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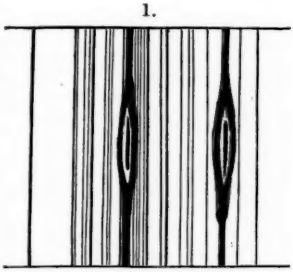
ART. XXXVII.—*Spectroscopic Notes*, 1879–80; by Professor C. A. YOUNG, Princeton, N. J.

I. *Double reversal of lines in Chromosphere Spectrum.*

THE magnesium lines of the *b* group, and the two D-lines of sodium have been seen several times (first on June 5, 1880) *doubly-reversed* in the spectrum at the base of a prominence.

A bright line first appears in the center of the widened dark lines; then this bright line grows wider and hazy at the edge, and a thin dark line appears in its center, as shown in the figure. The phenomenon lasts usually from ten minutes to an hour. It is evidently the exact correlative of the double reversal of the bright sodium lines, observable in the flame of a Bunsen burner or alcohol lamp under certain circumstances when the quantity and temperature of the sodium vapor in the flame are greatly increased.



Double reversal of D-lines.

II. *The* H*-lines in the Chromosphere and Sun-spot Spectra.*

In 1872, I found the H- and K-lines to be reversed in the spectra of prominences and sun-spots, as observed at Sherman, 8,000 feet above the sea. Until recently I have not been able

to verify the observation, except for a moment during the eclipse of 1878. During the past summer, however, I have succeeded in seeing them again, and with suitable precautions as to shade-glass, adjustment of slit to true focal plane for these special rays, and exclusion of extraneous light, I have no further difficulty with the observation. The spectroscope employed has collimator and view-telescope each of 1¼ inches aperture, and about thirteen inches focal length, and a speculum-metal Rutherfurd grating with 17,300 lines to the inch. A shade of cobalt blue glass greatly aids the observation. The solar image is 1¼ inches in diameter.

In the spectrum of the chromosphere, H and K are both *always* reversed. I have never failed to see them both when circumstances were such that *h*, the nearest of the hydrogen lines, could be seen.

Furthermore, H, in the chromosphere spectrum, is *always double:* that is, a fine bright line always accompanies the principal line, about one division of Ångstrom's scale below. The principal line seems to be exactly central in the wide dark shade, the other is well within the nebulosity. K on the other hand shows no signs of duplicity.

In the spectrum of a sun spot H and K are also, both of them, generally, though not always, reversed; and the reversal is not confined to the spot, but covers often an area many times larger in its neighborhood.

In the spot spectrum, however, H has never yet been seen double. The companion line of H is therefore probably due to some other substance than that which produces H and K; a substance prominent in the chromosphere, but not specially so in the neighborhood of spots. In view of the recent observations of Vogel, Draper and Huggins, it is natural to think that hydrogen is probably the element concerned. If so, it may be expected that H will be found doubled in the spectrum of a spot which reverses the hydrogen line *h*. I have not yet been able to test it in this way, as *h* is rarely seen reversed, though C and F occur pretty frequently. (See, further, a note by the author in the miscellany beyond.)

III. *Examination of lines in the Solar Spectrum which are given in the Maps as common to two or more substances.*

For this purpose a spectroscope of high dispersion has been constructed by combining the grating mentioned above, which has about four square inches of ruled surface, with a collimator and observing telescope each of three inches aperture and about 42 inches focal length, using magnifying powers ranging from 50 to 200. The apparatus is arranged upon a wooden frame work, and when in use is strapped to the tube of the

12-feet equatorial of our observatory, so that it is kept by the driving clock directed to the sun. An image of the sun is formed on the slit by an achromatic object glass of three inches aperture, in order to increase the light and to avoid the widening of the lines due to the sun's rotation. A large prism of about 20° angle was sometimes placed in front of this object glass (between it and the sun) to separate the colors before reaching the slit; and in examining the darker portions of the spectrum a concave cylindrical lens was sometimes used next the eye, like a shade glass, to reduce the apparent width of the spectrum and thus increase its brightness.

The grating is an admirable one, on the whole the best I have ever seen. But I have been greatly surprised at its excessive sensitiveness to distortion by pressure or inequalities of temperature. Although the plate is fully $\frac{3}{8}$ of an inch thick, and only $3\frac{1}{2}$ inches square, an abnormal pressure of less than a single ounce at one corner will materially modify its behavior, and a quarter of a pound destroys the definition entirely. In fact the plate is not naturally exactly flat, and to get its best performance it is necessary to crowd a little wedge gently under one corner. When it is in good humor and condition, however, the performance is admirable; one could wish for nothing better, unless for a little more light in the violet portions of the spectrum.

With this instrument I have examined the 70 lines given on Ångstrom's map as common to two or more substances. (At the time of the meeting of the American Association for the Advancement of Science, at Boston, I had finished the examination of only 47). Of the 70 lines, 56 are distinctly double, or triple; 7 appear to be single; and as to the remaining 7, I am uncertain; in most cases, because I was unable to identify the lines satisfactorily on account of their falling upon spaces thickly covered with groups of fine lines, none of which are specially prominent.

As a general rule the double lines are pretty close, the distance being less than that of the components of the 1474 line. Generally also the components are unequal in width or darkness or both, though in perhaps a quarter of the cases they are alike in appearance. The doubtful lines are the following, designated by their wave length on Ångstrom's map: 5489·2, 5425·0, 5396·1, 5265·8, 4271·5, 4253·9 and 4226·8. I strongly suspect 5396·1 and 5265·8 (which present no difficulty in identification), of being double, but could never fairly split either of them, and therefore leave them among the doubtfuls.

Those which show no signs of doubling, so far as could be seen, were: 6121·2, 6064·5, 5019·4, 4585·3, 4578·3, 4249·8, and 4237·5.

In respect to the lines 5019·4, 4585·3 and 4237·5 it is quite possible there may be some mistake as to the coincidence, since in his *tables* Thalen gives neither of them as due to iron. An accidental strengthening of the dotted line, which, on the map, leads up from the symbol of the element concerned, through the iron spectrum, would account for the matter, by making the line appear on the map as belonging to iron also.

As the facts stand, therefore, it is obvious that arguments which have been based upon the coincidence of lines in the spectra of different elements lose much of their force; it appears likely that the coincidences are in all cases only near approximations. At the same time this is certainly not yet demonstrated. The complete investigation of the matter requires that the bright line spectra of the metals in question should be confronted with each other and with the solar spectrum under enormous dispersive power, in order that we may be able to determine which of the components of each double line belongs to one, and which to the other element. If, in this research it should be found that *both* of the components of a double line were represented in the spectra of two different metals, and the suspicion of impurity were excluded, we should then indeed have a most powerful argument in favor of some identity of material or architecture in the molecules of the two substances involved.

IV. *Distortion of Solar Prominences by a diffraction spectroscope.*

Generally, in such an instrument, the forms seen through the opened slit are either disproportionately extended or compressed along the line of dispersion. The reason is this: if the slit be illuminated by monochromatic light, the images of the slit, formed on each side of the simple reflected image in the focus of the view-telescope (which is supposed to have the same focal length as the collimator), will have the same width as the slit itself only in one special case, not usually realized with a reflecting grating.

If the angle, between the normal to the grating and the view-telescope, is *less* than that between the normal and the collimator, the slit-image will be *narrower* than the slit, and a prominence seen through it will be *compressed* in the plane of dispersion. If the relation of the angles be reversed, then of course the distortion will also be reversed, and we shall have extension instead of compression.

The mathematical theory is very simple. Suppose the collimator and telescope to be fixed at a constant angle, as in the now usual arrangement.

Let angle between telescope and collimator = α.
Angle between telescope and normal to grating = τ.
Then angle between collimator and normal = $\varkappa = \alpha - \tau$.
Also, let space between adjacent lines of grating = s,
And the order of spectrum observed = n.
Then, by principles of spectrum formation, we have

$$\lambda = \frac{s}{n}\left\{\sin\tau - \sin\varkappa\right\},$$

λ being the wave length of the ray which is in the center of the field of view:

whence $$\sin\tau = \frac{n\lambda}{s} + \sin\varkappa.$$

Differentiating, we have at once

$$d\tau = \frac{\cos\varkappa}{\cos\tau}d\varkappa, \text{ or } \frac{\cos(\alpha-\tau)}{\cos\tau}d\varkappa;$$

which reduces to, $d\tau = (\cos\alpha + \sin\alpha\tan\tau)d\varkappa$. Distortion can only disappear in cases when this coefficient of $d\varkappa$ reduces to unity. Special cases—

1. If $\tau = \varkappa$ there is no distortion—but also no dispersion: it is the case of simple reflection.

2. If $\varkappa = 0$, the grating being kept normal to the collimator, then $d\tau = \sec\alpha\, d\varkappa$.

3. If $\tau = 0$, the grating being kept normal to the telescope (which in this case must be movable), then $d\tau = \cos\alpha\, d\varkappa$.

4. If $\alpha = 90°$, $d\tau = \tan\tau\, d\varkappa$.

5. If $\alpha = 0$, $d\tau = d\varkappa$, and there is no distortion.

This is possible only by using the same tube and object-glass both for collimator and view-telescope, the grating being slightly inclined at right angles to the plane of dispersion. The principal difficulty in this form of instrument lies in the diffuse light reflected by the surfaces of the object-glass. It is hoped that this may be nearly obviated by a special construction of the lens which will throw the reflected light outside of the eyepiece. An instrument on this plan is being made for Professor Brackett by the Clarks, for use in the physical laboratory at Princeton, and is now nearly completed.

Princeton, Sept. 27, 1880.

Note to the preceding Article, by Professor C. A. Young.—An observation made since my paper was written, leads me to modify this opinion, that the companion of H is due to hydrogen, and satisfies me that in all probability both H and K must themselves be hydrogen-lines. At 11 A. M. on October 7, a bright horn appeared on the S. E. limb of the sun. When first seen it was about 3′ or 4′ in elevation, but it rapidly stretched up and before noon reached a measured altitude of over 13′ (350,000 miles +) above

the sun's limb. It faded away and disappeared about 12.30. It was brightest about 11.30 with an altitude of about 8′, and at this time both H and K were distinctly, and for them, brilliantly reversed in it clear to the summit. H was not double in it to any notable elevation, though the companion of H was visible at the base of the prominence. The H- and K-lines also showed evidence of violent cyclonic action, just as C did. *h* was only faintly visible in the prominence; F and the line near Y were of course strong. But no other lines, either of sodium, magnesium, or anything else, could be traced more than a very few seconds of arc above the sun's limb. I am not able to say how long the H-lines continued visible, or to what elevation they extended afterwards, as I returned to the C-line to watch the termination of the eruption. If I remember rightly, this eruption reached a higher elevation than any before observed. There was (and is to-day) nothing on the sun's limb visible with the telescope which would account for it.

Princeton, Oct. 8.

ART. XXXVIII. — *On the thermo-electric power of Iron and Platinum in vacuo*; by Professor C. A. YOUNG, of Princeton, N. J.

EXNER, a few months ago, published a paper asserting that the thermo-electric power of antimony and bismuth is destroyed by removing them from all contact with oxygen, and immersing them in an atmosphere of pure nitrogen. From this he argues that the thermo-electric force in general is due to the contact of the gases which bathe the metals. The following experiment was tried to test the theory:

By the kindness of Mr. Edison and Mr. Upton a vacuum tube was prepared in Mr. Edison's laboratory, containing an iron wire, about two inches long, firmly joined to two platinum terminals which passed through the walls of the tube; the tube was exhausted until the spark from a two-inch induction coil would not pass $\frac{1}{8}$ of an inch in the gauge-tube, indicating a residual atmosphere of about one-millionth. The wire was heated to incandescence during the exhaustion, in order to drive off any possible occluded gases. The platinum wires outside the tube were joined to iron wires, the joinings being covered by glass tubes slipped over them, and a sensitive reflecting galvanometer was included in the circuit. By laying the tube and connected joinings in the sunshine, and alternately shading one or several of the joinings it was found that the electro-motive power of the joinings within the tube was precisely the same as that of those without, and the development of current just as rapid. There was no trace of any modification due to the exhaustion.

ART. XXXIX.—*Geological Relations of the Limestone Belts of Westchester County, New York;* by JAMES D. DANA. (With a Map, Plate V.)

[Continued from page 220.]

2. DISTRIBUTION OF THE BELTS OR AREAS OF LIMESTONE.

The limestone areas of the county have the distribution shown on the accompanying map (Plate V),[14] the colored portions representing them. The intermediate surface is occupied by the crystalline schists—mostly mica schist and gneiss—as already explained. I have not attempted, in my study of the rocks, to ascertain the outlines of the areas of these schists, because my purpose was accomplished when their conformability and their conformable relations to the limestone beds were ascertained, and the time I could command, without aid in the work, was insufficient for a complete survey of the county. Moreover, the distinction of mica schist, micaceous gneiss, thick-bedded feldspathic gneiss, hornblende schist, is, in many parts, of no stratigraphical value, these unlike rocks, as has been stated (p. 29), often occurring in alternations and graduating into one another in the direction of the bedding as well as transverse to it, rendering a correct mapping of their distribution next to impossible. There are, however, areas of the hard feldspathic gneiss in which micaceous bands seldom occur, that might, after careful study, be more or less perfectly laid down. The limestone areas often contain, as stated on p. 29, more or less mica schist or gneiss, which is not indicated on the map, partly owing to the small scale of the map, but largely to the fact that the two are often so interstratified that their separation is hardly possible, especially under the difficulties from the covering of alluvium or drift. In several cases the schist is an overlying or underlying stratum, included in the flexure; and further study may prove this to be true in some not so explained in the descriptions beyond. A geologist, on commencing his study of the limits of these limestone areas, would be likely to give less weight than I have done to the evidence from the form and flat bottom of the valleys, while with longer study he would be pretty sure to be satisfied with the conclusions arrived at.

The T-shaped symbols on the map indicate the strike and dip of the beds, both of the limestone and schist; the top

[14] This map, apart from its geological facts, is Colton's pocket map of Westchester County reduced one-half, with also the roads and most of the names of places omitted. A slight change has been made in the coast west of Cruger's, and the Putnam County portion has been put on from Putnam County maps. By photographing it double of its present size, the position of the areas and T-symbols with reference to all roads may be ascertained on comparison with Colton's map.

of the T shows the direction of the strike, and the stem that of the dip (or pitch) of the beds for the locality situated at their junction. Moreover, the length of the stem as compared with that of half the top of the T is made to give an approximate idea of the amount of dip, according to the following scheme: ratio for 80°, 1 : 4; for 70°, 1 : 3; for 60°, 1 : 2; for 50°, 1 : 1⅓; for 45°, 1 : 1; for 35°, 1½ : 1; for 25°, 1½ : 1; for 15°, 2 : 1.

In the following descriptions of the belts I speak: *first*, of the SOUTHERN section of the county, from New York Island to White Plains; *secondly*, of the MIDDLE section, from White Plains to Croton Lake; and *thirdly*, of the NORTHERN section, north of the latitude of Croton Lake. The areas are numbered on the map, and these numbers are used in connection with the descriptions.

The following pages contain only the general facts respecting the several belts—their position and features; the average strike and dip; the characteristics of the limestone, and the kinds of adjoining rocks and their relations as to position. The details with regard to the various directions of strike and dip at all the points marked by symbols on the map and for other points not thus indicated, which make part of this paper as prepared, are reserved, with other details, for an Appendix.

a. *Southern Section of the County.*

Three areas or belts commence in New York Island and extend two to four miles into Westchester County. The adjoining rocks are mica schist and micaceous gneiss and in some parts thick-bedded gneiss.

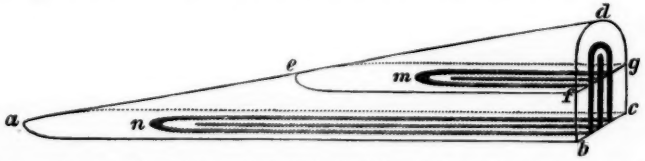
Area 1.—The eastern of these three belts, which may be called the Tremont, extends from Fordham southward to Harlem River, and from thence into New York Island. It reaches Harlem River by *two* lines, a *western* at Mott Haven and an *eastern* at the mouth of Morris Mill brook, west of Brook avenue. The main strike is N. 18–25° E.[15]

The *western* of these southern terminations, or that of Mott Haven, shows itself just east of the railroad, south of the Mott Haven railroad station, in two limestone hills which will soon disappear from grading. The rock on the west or opposite side of the railroad at this point is somewhat contorted mica schist; and layers of the same kind of schist are involved among the beds of the northern of the hills. Near the Mott Haven depot, the limestone passes to the west side of the railroad, and from thence it continues northward on both sides. The *eastern* line has large outcrops of purer limestone near

[15] The angle here (and so elsewhere in this paper) is corrected for magnetic variation. In stating the *dip*, only the point of the compass is mentioned in a general way, the exact direction being at right angles to the strike.

142d street, and at many points to the north.[16] The eastern and western lines become united in one wide belt in Morrisania which continues northward through Tremont to Fordham. Toward Harlem River the interval between these two lines is low and flat, without outcrops of rock at the present time except some micaceous gneiss to the eastward. On 142d street, east of the brook, there is a locality of hydrous anthophyllite and impure serpentine which will soon be graded away. The dip of the beds of limestone in Tremont, and at points south of the place, indicate that the belt of limestone from Fordham southward is a denuded anticlinal fold; and assuming that the limestone of the belt divides southward, as the facts appear to show, the axis of the fold has a small *northward* pitch. This division of the limestone to the south into two bands, an eastern and western, separated by intervening schist, would come from the wearing down of such a fold to a horizontal surface.

That this statement may be understood by readers not familiar with the subject, the accompanying diagram, giving a general idea of the condition supposed, is here introduced: it is intended to represent an anticlinal fold with an inclined axis but vertical axial plane, in which layers of gneiss are enveloped by a stratum



of limestone. In the horizontal section, *e f g*, the limestone of the two sides is in one connected mass from *e* to *m*, but in two bands separated by intervening gneiss from *m* to *f g*. The same also is shown in the section *a b c*.

Professor Gale states[16] that the gneiss along 4th avenue from 118th to 120th street is in places half limestone; and Professor D. S. Martin has observed[17] the same on 124th street; and these localities are in a line with the Mott Haven and Tremont belt, and indicate its southward extension into New York Island, as recognized by Mr. R. P. Stevens.[18]

This Tremont belt is widened on its west side in Morrisania, over Fleetwood Park, in consequence of a second anticlinal (see map), but one *having the axis inclined southward*, or in the opposite direction from that of the main belt. That the axis has this inclination is shown by the strike and dip of the mica schist which divides the northern end of this western extension, and its widening northward. At a section of the schist on the north side of the park the dip is in opposite directions;

[16] Mather's N. Y. Report, p. 593.
[17] Proc. Lyc. Nat. Hist. New York, 1871, i, 222. [18] Annals, ibid., viii, 116.

and farther north on the Morrisania side, the anticlinal is a more gentle one. The limestone here extends over half a mile west of the railroad, the western limit being nearly half way up the slope that makes the high western side of the park.

Area 2.—The *second* belt, or that of "the Clove," follows Cromwell's Creek, north of Central (or McComb's Dam) Bridge and the brook emptying into it. The most southern outcrop occurs about a mile north of the bridge above the crossing of the brook by Central avenue. Some of the layers at this place contain much chlorite in bright green scales. It outcrops again near the "Club House." North of this the presence of limestone is indicated only by the form and definiteness of the valley and by the outcropping schist on its sides. The limestone varies much in strike, owing to contortions, but the adjoining schist gives for the strike about N. 25° E.

This belt probably continues southward into New York Island, as R. P. Stevens has observed,[19] who says that in grading east of 6th avenue in 132d street, limestone was cut through.

Area 3.—This limestone belt is a prominent feature of the north end of New York Island. From the island it extends three miles northward into Westchester County, along Tibbit's Brook. At Kingsbridge a deep cut is made through it for the Hudson River railroad. North of this place it is not in sight along Van Cortland's Lake, but outcrops at points in the valley of Tibbit's Brook above this to if not beyond the stone-arched bridge, nearly three miles from Kingsbridge. Crumbling masses of the limestone lie on the eastern approach to this bridge which, as I am informed by the superintendent in its construction, Mr. John Wetherill, were quarried in that vicinity, his letter saying he "opened several quarries for stone for the bridge," and found "all the rock of the valley to be limestone of a poor kind." The mica schist on the east side of the valley along the Croton Aqueduct, south of the bridge referred to, has the strike N. 20° E., and that at Kingsbridge N. 37°–40° E., the dip in both 70°–75° to the eastward.

The limestone area from Kingsbridge southward was imperfectly mapped by Dr. L. D. Gale.[20] South of the Harlem, it widens on its *eastern* side for the first mile and just north of the east-and-west inlet called Sherman's Creek, extends from a point west of the "Kingsbridge road" or Inwood street to the Harlem River. Thence its *western* side has a narrow continuation southward along the Kingsbridge road in a well-defined valley wall-sided on the west, while its broad middle portion is fronted, south of Sherman Creek, by hills of micaceous gneiss; and it is probable, judging from its strike, that

[19] Annals Lyc. Nat. Hist. New York, viii, 116.
[20] In Mather's N. Y. Geol. Rep., Plate I.

the eastern side has its narrow continuation down Harlem River, as is suggested on the map, although no outcrops appear to prove it. If this be the correct view, the area as a whole resembles in form the Tremont or No. 1, and, like that, owes the forked character to its being the remains of a denuded fold. The most southerly outcrop of the limestone on the Kingsbridge road is, as found by Dr. Gale, near 204th street, or about 500 yards south of Inwood street, where the width of the valley is nearly 300 yards. The valley fades out and is closed by the gneiss at 182d street; the limestone may exist beneath as far as 190th street, if not beyond.

The supposed Harlem River or *eastern* fork of the belt has an argument in its favor in the existence of a well-defined flat-bottomed valley, formerly more or less marshy and still so about its mouth, along 8th avenue in the direct line of the river. This valley, long since styled by Dr. Gale "the valley of 8th avenue," lies between 7th and 9th avenues, and has a wall of nearly vertical gneiss 40 to 80 feet high on part of its western side. The depression is well defined to 115th street, and is distinct to 110th.[21]

Over the more southern part of New York Island, in the line of the western fork of the belt, there are some localities where serpentine or "hydrous anthophyllite" occur in the gneiss; and, although no connection with this area can be traced, it is of interest to note them at this place. Dr. Gale states that from 59th street on 10th avenue to 63d street at the river, there existed a vertical bed of hydrous anthophyllite having gneiss on the east side and granite on the other.[22] Mr. I. Cozzens, in a volume on New York published in 1843, mentions the occurrence of black serpentine between 10th avenue and the river and between 54th and 62d street, in a bed twelve feet wide containing also limestone and talc. At 157th street, 100 feet west of 10th avenue, a mixture of limestone and serpentine has been observed.

North of Area No. 1, which stops at Fordham, the line of outcropping limestone is shifted a little eastward to the course of the valley of the Bronx, in which occur, at intervals, the areas numbered 4, 10 and 11; and from No. 3, there is a shift westward, to the course of the valley of Saw Mill River, along which there are, at Yonkers, two small parallel areas 7 and 8, and farther to the north, numbers 14 and 15. The line of No. 2 may perhaps be represented in No. 9, which follows the course of Grassy Sprain Brook. To the east are two areas, nearly in the same line of strike, numbered 5 and 6, which are the serpentine areas of New Rochelle and Rye.

[21] Whether the fold in this limestone is a synclinal or anticlinal, facts do not positively decide. This point will be further considered in the appendix.

[22] Mather's N. Y. Geol. Report, p. 582.

As stated, these limestone areas follow the courses of the rivers mentioned; but the historical fact in each case is this, that the river follows the course of the limestone, the softness of the latter rock causing it to yield easily to eroding or denuding agents.

Area 4.—In this area, ledges of limestone show themselves just above the point of junction of the Harlem and New Haven railroads, and were cut through in grading for the tracks. The valley of the Bronx has here a flat marshy bottom and this continues, with the same bordering schist northward to West Mt. Vernon and southward to and below Williams Bridge, indicating the probable presence there of the limestone, as indicated on the map. I was informed at Williams Bridge of the former existence of an outcrop of limestone visible at low water, on the river just below the bridge, but failed to find any now. The strike of the mica schist adjoining the belt on the west is N. 20°–29° E., and dip 65°–75° E.; and west of the river at Williams Bridge N. 20° E., dip 65°–75° W.

Areas 5 *and* 6.—These areas of serpentine with some calcareous material, at New Rochelle and Rye, have been partly described on page 30. The map makes manifest, by its T-symbols, the conformability of the mica schist and micaceous gneiss between the West Mt. Vernon limestone and the area of New Rochelle; and also shows that the New Rochelle and Rye areas are nearly on the same line of strike. There is no essential difference in the schist adjoining them. The dip of the rocks around the latter afford evidence that it is situated along the axis of a local anticlinal. From Stamford westward to the Harlem the dip is in general westward; but at Portchester on the way toward Rye the dip changes to eastward, and then becomes westward again west of the area. The symbols indicate the wrenching the beds underwent in the making of the fold, and show that the fold was steepest and narrowest to the southwest, and had its axis inclined to the south-southwestward.

The positions of these areas with reference to the schists, and the conformity of the schists as to kind from Rye to New Rochelle and from the latter to Mt. Vernon, are facts favorable to the view that they correspond in origin to the limestone areas of the more western parts of Westchester County.

Over the elevated country between this region and the vicinity of the Harlem railroad, the rock changes to a hard gneiss, thick-bedded and granitoid; and, moreover, outcrops are few, the surface being one of wide fields under cultivation; and this continues northeastward into Western Connecticut. It appears that upon these high plains the earthy material or drift left by the glacier has remained almost undisturbed, instead of being cut through to the rocks as on the slopes that

lead to the Sound on one side and to the valley of the Harlem railroad on the other. Along this railroad, limestone again appears, and before reaching it there is a return to micaceous gneiss and mica schist.

Areas 7 *and* 8.—Of these areas at Yonkers, number 7, or the western, follows the course of a north and south bend in Saw Mill River, and has a width of at least 100 feet. It lies beneath the city of Yonkers, and I am indebted for the facts respecting it to Mr. W. W. Wilson, Engineer of the Yonkers Water Works. Indications of a more eastern belt (No. 8) occur along the Saw Mill River valley, just north of the city, in the existence of loose masses of limestone on the east side of the river. But I found no outcrops in my observations along that southern portion of the valley, and its width and length are therefore undetermined. It is possible that the two areas may be one cut into two by a fracture and a horizontal or oblique faulting. The rocks are not open to view for a decision of this point.

Area 9.—This small area, on Grassy Sprain Brook, has a width to the south of 500 yards. The strike is N. 10°–20° E.

Areas 10, 11 *and* 12.—East of the last, on the River Bronx, a limestone belt begins near Bronxville, which, in Tuckahoe and Scarsdale, is the site of many marble quarries. The strike is N. 22°–27° E. This limestone belt tapers out to the south, while to the north, and for the most of its course, it is divided into two parts separated by a band of mica schist and gneiss. It is probable that the whole corresponds to a decapitated anticlinal having its inclined axis dipping at a small angle to the south. To the north of the Scarsdale depot the eastern line is not traceable, and the western line appears to thin out.

Limestone re-appears on the Bronx 100 to 200 rods to the north of the last, just east of the railroad—that of area 11—and thence continues to Hartsville, where the strike is N. 17°–24° E. A narrow strip of low land follows the east side of the Bronx nearly to White Plains, and it is possible that the belt is continued beneath it. About a mile and a half north of White Plains a small area of limestone shows itself, No. 12, the most of the exposure of which is due to the removal of the stratified drift.

Area 13.—Again, along the Hudson, north of Yonkers, occurs the Hastings belt. It was formerly visible at Dobb's Ferry; and it was cut into, as I learn from Mr. Benjamin S. Church, when excavations were going on there for the Croton aqueduct. This river-border belt may have much greater length than is given it on the map, and greater width also; for the high terrace deposits (stratified drift) of the valley conceal all shore rocks. The adjoining schists are gneiss with nearly vertical dip.

b. *Middle Section of the County.*

Areas 14 *and* 15.—In Saw Mill River valley—the same that has its limestone belts near Yonkers—a large limestone area commences, about two and a half miles north of Ashford. It widens much at East Tarrytown and continues northward to a near junction with the Pleasantville area, No. 15. The mean strike for its northern two-thirds is about N. 30° E.

The Pleasantville area also is broad and sinuous in course. It terminates just north of the Chappaqua depot. The strike near Unionville is N. 24° E., and at Pleasantville (where there are large and valuable quarries) mostly N. 30°–40° E. A small independent limestone area (No. 15*a*) occurs just east of the Pleasantville area.

Areas 16 *and* 17.—The long known Sing Sing belt commences south of the depot on the Hudson and extends north-northeast nearly to the north boundary of the town of Ossining; and it also branches eastward up a small valley toward the Camp Woods, a furcation which seems to indicate the existence of an anticlinal fold with the axis dipping southward, which was made thus to furcate by denudation as in the case of the Tremont area, No. 1, the opposite direction of pitch in the axis making the difference in the direction of the furcation.

No. 17 is a small area of contorted limestone giving nothing reliable as to strike or dip.

Areas 18 *and* 19.—A small Croton limestone area, No. 18, exists half a mile east of the village, without distinguishable planes of bedding. Mica schist bounds it on the north; but it may extend in the opposite direction to the bay, where drift and alluvium conceal the rocks.

South of Croton River a narrow area, No. 19, extends from near a bridge northeast of the last, called Quaker Bridge, to the furcation of the river at Huntersville, about two miles, following mostly the west side of the road. Its southern portion has a westward bend, with which the strike of the limestone corresponds.

Areas 20, 21 *and* 22.—No. 20 is a very small area at Merritt's Corners among contorted rocks, giving uncertain strike and dip. No. 21, to the northeast, on the east border of Croton Lake, may be the margin of a long belt following the course of that part of the lake, though such an inference is not suggested by the observed strike. No. 22 is another small area of contorted limestone near Bedford station on the Harlem railroad.

Area 23.—No. 23 lies to the east of the Pleasantville belt on the borders of New York and Connecticut, and follows the course of Byram River to its source in Byram Lake. It was first laid down on Percival's geological map of Connecticut

and the limits assigned to it by him are here retained. I found the limestone outcropping along the eastern half of the broad valley. The mean strike to the south is N. 10° E.; and the same east of Armonk. The limestone exists in the lake and was quarried near the northeast when the water was quite low; but I found there no place for observing the strike excepting in the schists about the lake, where the rocks are greatly contorted (see the T-symbols on the map), as if situated about the end of a fold.

Areas 24 *and* 25.—These areas, to the northeast of Byram Lake (first mapped by Percival), are both bow-shaped, but in opposite directions. No. 24 follows a valley along the headwaters of Mianus River, and No. 25, that of Stone Hill River. The limestone outcrops to the east of the village of Bedford show that the bend corresponds with a change in the strike of the beds. In the Stone Hill River belt the strike of the bedding, in its southwestern part, is N. 55° E., but in its eastern, N. 23° E., showing that the bow-shaped form of the valley and outcrop was determined by the direction of the bedding.

c. *Northern Section of the County.*

Some of the areas in the northern part of the Middle section of the county have been shown to tend toward east-and-west in trend and in the strike of the beds. In the Northern section the larger part of the areas have approximately this abnormal course, the normal northeast trend existing only in a large eastern and in some of the northwestern areas.

Area 26.—This is the large eastern area of northeast, or rather north-northeast, trend, just alluded to. It extends into Connecticut and was hence studied by Percival; and our delineation of it is taken from his map. It has a range of mica schist and gneiss situated more or less regularly along its center, which is partly hornblendic, and in view of this fact, it is probable that the area is that of a denuded fold.

Areas 27 *and* 28, *and the small areas in the Verplanck Peninsula.*—These areas have been described on pages 205, 215. I add here that while the rocks on the *north* side of the Cruger's limestone (number 27) are mica schist, and micaceous gneiss with soda-granite, quartz-dioryte and various chrysolitic kinds, those on the *south* side are the ordinary gneisses of Westchester County, containing chiefly orthoclase with some triclinic feldspar, and vary in color from flesh-colored and grayish-white where the feldspar predominates, to black or grayish-black where mica (biotite) is abundant. Of the small limestone areas of the Verplanck Peninsula, No. 2 (see map on page 195) has black dioryte on its northeast side, but on the opposite, and plainly

conformable with it, common gneissoid mica schist, and in the schist there are thin beds of limestone.

The Verplanck belt, No. 28, has the normal northeast trend, the strike averaging N. 35° E. (dip 60°–70° E.). But toward the Point there is much variation from this, the strike a third of a mile from the Point changing from N. 44° E. to N. 63° W., and near the river, south of the more northern brickyard, from N. 50° E. to N. 74° E., the dip 40°–70° E.

Areas 29, 30 *and* 30 *A.*—Number 29, another of the northern belts having a northeast course, extends up Sprout Brook Valley or Canopus Hollow, into the Archæan area of Putnam County. Its length is nearly five miles. It adjoins quartzyte conformably at the mouth of the brook (p. 214) with the strike N. 47°–54° E., and dip 60°–70° E.; near the crossing from Peekskill to Annsville, a hydromica slate lies between it and the quartzyte; and just below Annsville, near the river, it lies against Archæan hornblendic gneiss. The most northern outcrop I have found is situated to the west of the south end of Oscawana Lake. The limestone has been already described as for the most part but slightly crystalline, especially in its more southern portion. Two-thirds of a mile north of the Putnam County line, under a bridge over the stream, quartzyte in beds lies against the limestone; and above this at some of the outcrops the limestone is interstratified with mica schist.

The Canopus Hollow belt appears to be continued southwestward, across Hudson River, in the limestone of Tompkins Cove at the foot of the Archæan Highlands. This limestone forms a prominent bluff facing the water and has long been worked for lime. It is in its eastern part a whitish, compact, fine-grained, crystalline limestone, but to the westward a gray, uncrystalline rock. The area extends south-southeast nearly to Stony Point village, about two miles, and disappears because beyond this it is overlaid by the Triassic Red sandstone. The average strike is N. 20° E., and the dip 35° to 60° E. Just southwest of Stony Point it is covered by a grayish to reddish limestone conglomerate made up of pebbles and rounded stones which are worn fragments of the limestone bed; and this conglomerate is referred by Professor G. H. Cook to the Triassic.

Although the average strike of the beds of the limestone is as above stated, there are great variations at the Cove, they becoming even east-and-west in some parts. At the Cove the limestone has on its *western* side, a blackish, fragile, partly graphitic slate or hydromica schist (called talcose slate by Mather), resembling that of Canopus Hollow north of Peekskill, which, half a mile south, changes to a quartzose rock, partly feldspathic, resembling the granitoid quartzyte of Peekskill.

On its *eastern* side, toward the base of Stony Point, it is followed conformably by mica schist and micaceous gneiss, (good contacts being visible), having the strike (like the beds of limestone adjoining) N. 14°–20° E., and dip 60° E. This thin-schistose micaceous rock is followed eastward on the coast by a massive granitoid rock which is intermediate lithologically between soda-granite and ordinary granite, the feldspar being half orthoclase. Then succeed the noryte and chrysolitic rocks of the areas marked z' and z on the map on page 195, then the soda-granite of y, and lastly, near the extremity of the Point, the mica schist or micaceous gneiss of x. The succession along the *north* side of the Point from west to east thus is: (1) schist, (2) semi-soda-granite, (3) chrysolitic rocks, (4) soda-granite, (5) schist. Going between these points by the *south* a wholly different state of things is found; *schist continues all the way; and the strike varies from N.* 20° *E. where it adjoins the limestone, through northwest and west-and-east, to N.* 62° –70° *E.*, which is the strike on the south side of the Point, south of the eastern soda-granite, as already stated (page 213). This change of strike in the schist indicates a broad flexure, with the sides diverging to the northeastward. Inside of this flexure there are first the soda-granite, and then at or near the middle the chrysolitic rocks. But, as I have found, the soda-granite is interrupted south of the chrysolitic area, schist having its place, as if by a change of soda-granite to schist. The schist is mostly even in its bedding except about the bend, where it is much contorted. As near Cruger's, transitions exist of the schist into the soda-granite with the rock very garnetiferous at the junction—a good example of which may be seen northeast of the house on the south side of the point.

Notwithstanding doubts on some points, there is no question that the schist has the flexure pointed out, and is one continuous stratum; and that the limestone is an adjoining stratum, and must have participated in the flexure. Further, since the dip of the schist on both the south and west sides is toward the axis of the flexure, *the limestone stratum is probably an underlying one*, which would make the schist and soda-granite superior to it in stratigraphical position. Now *since the Cruger's limestone adjoins a schist that is similar to that of Stony Point in kind, and position, and in all of its relations to the soda-granite, the Cruger's limestone must be of the same stratum with the Tompkins' Cove limestone; and, if so, it is one, also, with the limestone of Canopus Hollow.*

The area Number 30 is like 29 in extending along a prominent valley—Peekskill Hollow—northeastward *far into the Archæan.* The most northern locality of limestone which I have found is a mile and a half above Tompkins' Corners (west of

the mouth of Roaring Brook) about seven miles northeast of Oregon—a village on the borders of the two counties. It is a fine-grained white to blue limestone and occurs with a well characterized quartzyte in conformable beds, unconformable to the Archæan. It shows itself also about Adams Corners, two to three miles above Oregon, and near Oregon, at the spot marked by the T-symbols. Below this, there are no outcrops of rock, and its limits southwestward are consequently undetermined. This valley—Peekskill Hollow—is so narrow for much of the way above Adams Corners that it is probable that the limestone is not continuous, but that the present spots are what is left after long denudation. There can be no reasonable doubt that the large, open valley was once the course of a broad band of the limestone for the whole of the seven miles in Putnam County.

The facts observed with respect to area 30 A and the associated mica schist and quartzyte are mentioned on page 214. Mather speaks of an outcrop of limestone, with "hornblende rock adjoining it on the east," at the Lower Dock of Peekskill. This spot is now graded over and the observation cannot be confirmed; but it lies in the line of this area where it would reach the river. If it is correct, the rock which adjoins the limestone in this part is noryte, and no mica schist intervenes between this rock and the limestone, as it does 150 yards north.

To the eastward, in Peekskill village, there is limestone in the mica schist on the Crom Pond road, according to Mather; and north of the Academy grounds there appears to be an outcrop in the road; and this lies on the south margin of the valley in which this area occurs. The limit of the area eastward is not determinable; it may possibly connect with that of Peekskill Hollow, though this seems to be hardly probable.

Areas 31, 32, 33, 34 *and* 35.—Number 31, in the southern part of Somers, east of Hallock's Mills, trends nearly east and west; it is made up of two parts, a western and eastern, the strike in the former N. 53° E., and that in the latter east-and-west.

Number 32, in North Somers, east of Somers Center, is another nearly east-and-west area, the strike averaging N. 71° E. Numbers 33, 34 are small areas, too limited in extent of outcrop to determine their characters, beyond that of an approximately east-and-west trend. No. 35, or that of Lake Waccabuc, has, according to Percival, the extent given it on the map. I have seen outcrops only between the lake and the pond west of it.

Areas 36, 37 *and* 38.—The large North Salem belt, No. 36, first laid down by Percival, is six miles long, and has an east-and-west course. It has in some parts a band of gneiss

along the middle, indicating that it is a denuded fold. Number 37 follows the course of Beaver Pond, and has a precipitous face of rocks on the north. Number 38 is like the preceding in course, and in its being an extension of a Connecticut area—that of Mill-Plain valley, which reaches to Danbury. Its most western outcrops are in the road between Brewster and Danbury, less than a mile and a half from the former place. These two east-and-west belts on Percival's map I at first viewed with distrust, since the fact expressed on the map was not fortified by any statements as to the strikes which he had obtained. But I found on examining the regions that the adjoining schist (gneiss and mica schist), as well as limestone sustained his map. The maker of Mather's map had the same wrong preconceptions, and put it into his delineation of the areas. The T-symbols on the accompanying chart make manifest the fact as to this position of the rocks.

3. General Conclusions.

Taking into consideration the facts that have been presented from Westchester County, those brought out with regard to the Green Mountain region of Vermont, Massachusetts, Connecticut, and Dutchess County in Eastern New York, and the observations on record from the region of the Highlands in New York and New Jersey, we have, I believe, sufficient grounds for the following statements.

The limestones and adjoining schists of Westchester County—

(1) *are one in series and system of disturbance.*

(2) *are probably part of the Green Mountain system.*

(3) *are younger than the Highland Archæan.*

(4) *are probably of the age of the Lower Silurian*—the Primordial or Cambrian being included under this designation.

(5) There are reasons for concluding also that they were made before the channel of the Hudson was cut through the Highlands; and the question will come up, finally, What bearing this may have had, if any, on the origin of the rocks of the "Cortland series."

1. *The Limestone and adjoining Schists one in series.*

From the facts presented on the map and in the preceding pages, and better from the special details as to the position of the beds and kinds of rocks given beyond in the Appendix, the important conclusion is derived that, throughout the county, the limestone of the several areas is conformable in its bedding to the schists which in each case adjoin it. There are contortions in the limestone, and in many places also in the schists; but this is so because such uplifting necessarily involved a warping of the beds, and was often attended also by

torsion. The limestone areas are commonly the positions of upward or downward folds or flexures, with usually the axis in each case inclined in the direction of the fold and the axial plane also inclined to one side or the other; and in the making of them, contortions should have been often produced. The small serpentine area at Rye, No. 6, is a striking illustration; and the north end of area 23 is another. The varying strikes between areas 24 and 25 show the effects of torsion and the interference of the near extremities of two curving folds.

2. *Relation to the Green Mountain System.*

With reference to the relation of the rocks of the county to the Green Mountain system there are the following facts:

(1.) Westchester County is topographically a southern part of the Green Mountain elevation. The axis passes along the interlocking borders of Connecticut and New York, and extends on through New York Island.

(2.) The grade of metamorphism follows the same rule as to the north—that is, it is of greatest intensity to the eastward and to the southward. It is in accordance with this that the least degrees of metamorphism are found in the limestone and associated schists of the vicinity of Peekskill, in the northwest corner, while along the central and eastern portions of the county, and in the western, also, south of Croton, the crystallization is commonly very coarse. The limestone of the Verplanck, Cruger's and Croton areas (Nos. 28, 27, 18), are of intermediate texture.

(3.) The limestones have the same kinds of associated rocks, that is, of mica schists and gneisses, as in the eastern and more metamorphic portion of the region in Connecticut—a fact deserving mention though not of great weight.

(4.) The limestones have a like paucity in disseminated minerals and similar occurring species with those of Connecticut; mica (muscovite) and tremolite being the common kinds, white pyroxene of occasional appearance, and graphite sometimes present.

(5.) The ordinary normal trend of the rocks, N. 20° E. to N. 30° E., is very nearly the average trend of the beds of limestone and associated rocks in the Green Mountain system.

Through the Southern and Middle sections of Westchester County this trend or strike is almost uniform, except where great contortions occur; and on the east, this strike is continued northward into Connecticut. In the Northern section, on the contrary, the exceptions, excluding its eastern and northwestern portions, are almost universal; and the question is a serious one whether another system is not here represented. But, in opposition to this inference, we observe that the limestones and

associated rocks are the same in character in both parts; moreover, there are in some portions of the Middle section large bends, and in the region of limestone areas 19, 24 and 25, a bend from nearly east-and-west to nearly north and south. Area 25 cannot be separated by its associated rocks from the adjoining area 26, which is normal in trend or in the strike of its rocks. Again, while area 29, to the northwest, is normal in its course, area 30 A, which is essentially conformable as the intervening rocks show, is nearly east and west. Through these areas or belts of intermediate curves the system of the Middle and Southern sections of the county graduates into that of the Northern. My study of the position of the beds has not resulted in the discovery of any want of conformity between the rocks of different areas except such as can be traced to contortion. The east-and-west and northeast trends appear therefore to have been results of one and the same system of disturbance.

This argument with reference to the relation of the rocks to those of the Green Mountain system cannot be regarded as wholly satisfactory without a fuller presentation of the facts from the adjoining portions of Connecticut, and this will be given in another number of this Journal.

3. *The limestone and associated rocks are younger than the Archæan of the Highlands.*

The proof with regard to this relation to the Archæan rocks of the Highland area must be looked for along those limestone belts that most closely adjoin it. The lithological evidence as to diversity of age is weak; for while the gneisses of Westchester Co. are usually much more schistose and micaceous than the Archæan, and while, also, the Archæan gneisses are generally hornblendic, there are gradations between the two in both respects which make the application of a lithological test very perplexing. The condition and position of the limestone areas which border the Archæan in the vicinity of Peekskill afford us a safe conclusion, and this is strengthened by other facts from the western portion of this area on the west side of Hudson River.

The region affords three classes of decisive facts.

(1.) The rock adjoining the Archæan in the southern part of Canopus Hollow near Annsville is a bluish slightly crystalline limestone, so slightly that it might for all this contain fossils. This nearly uncrystalline condition characterizes the limestone for a mile up the valley though not in so extreme a degree; and beyond this it has nowhere the coarseness of the limestones to the south.

(2.) The limestone area is bordered on its west side, opposite

Annsville, by a fine-grained hydromica schist which looks as much like argillyte as the Dutchess County slates at Poughkeepsie that contain Hudson River fossils; and this argillyte-like rock occurs at other points up Canopus Hollow, forming hills on its eastern side, and outcropping occasionally on the west side. Its feeble degree of crystallization corresponds with that of the limestone. Both rocks in this respect are like the rocks of Dutchess County, and unlike anything found in the Highland Archæan.

(3.) The limestone at the locality near Annsville lies unconformably against hornblendic Archæan gneiss, its beds much contorted; and another similar case of unconformability exists on the east border, half a mile northeast. In general, both in this valley and Peekskill Hollow, actual contacts are not in sight owing to the earth or alluvium of the valley; and the upturning of the limestone and its associated schist has usually placed them in near conformity to the strike of the Archæan rocks. Still, the unconformability is in some places distinct. Moreover the mica schist involved with the limestone in the more northeastern outcrops is very unlike the hard hornblendic gneiss of the adjoining Archæan.

The limestone of Peekskill Hollow is very finely crystalline, even at its most northeastern outcrop, and at Oregon it is associated with the same argillyte-like hydromica slate that occurs along Canopus Hollow.

West of the Hudson River at Tompkins Cove, where a high bluff of the limestone stands on the river directly facing Verplanck Point, much of it is even less crystalline than near Annsville, and the more western portion of it differs little from the ordinary blue limestone of uncrystalline regions. I had slices made for microscopic study, but detected nothing organic. The slate which lies between it and the Archæan gneiss of the adjoining Highlands—talcose slate of Mather—is only a glossy argillyte in aspect though representing (as Mather observes) the hydromica schist of Canopus Hollow east of the Hudson. No direct junction of the Archæan is here visible. A semi-crystalline condition also characterizes, for the most part, the limestone of the Verplanck belt,[23] and that of Cruger's area. We find thus that the nearer to the Highland Archæan the less is the degree of crystallization, which would not be the case if the rocks were of the age of the Highland Archæan.

Inasmuch then as the Westchester rocks are newer than the Highland Archæan, the limestone belts of Canopus Hollow and Peekskill Hollow occupy Archæan valleys—valleys that

[23] The limestone of the *small* areas of the Verplanck peninsula, situated in the hornblendic and augite rocks, is often graphitic and more coarsely crystalline than that of the Point.

antedate the era of the limestone; and these broad and strongly marked valleys were arms of the sea in that era, stretching a third to a half of the way across the Putnam County Highland region. In these extensive bays the limestone and the associated stratified deposits, now slate or schist and quartzyte, were formed. Since, also, the limestone now in these valleys is what is left after long ages of denudation, it has but a small part of the breadth and thickness which belonged originally to the formation.

From the fact of the preëxistence of the Archæan Highlands, we appear to have also a reason for the contortions of the rocks in the northern half of Westchester County, and for the nearly east-and-west courses in the bedding. For in the upturning or flexing of the strata, which took place, and which put the beds in nearly vertical positions over the whole county, the Archæan stood as a stable barrier on the north; against it the rocks were forced by the lateral pressure that produced the great results. The *mass* of the Archæan has here an easterly trend, much more easterly than that of the New Jersey Archæan, although the strike of the Archæan beds is generally northeast.[24] The direction of the pressure and the resistance to movement in such a barrier, are the chief of the conditions that would have determined the direction of the folds, fractures and faults in the disturbed strata.

[To be continued.]

ART. XL.—*Paleontological and Embryological Development.* Address by ALEXANDER AGASSIZ, Vice-president of Section B, at the recent Boston Meeting of the American Association for the Advancement of Science.

[Continued from page 302.]

Taking up now the embryological development of the several families which will form the basis of our comparisons, beginning with the Cidaridæ, we find that in the earliest stages they very soon assume the characters of the adult, the changes being limited to the development of the abactinal system, the increase in number of the coronal plates, and the modifications of the proportionally gigantic primary radioles.

In the Diadematidæ the changes undergone by the young are limited to the gradual transformation of the embryonic spines into those which characterize the family, to the changes

[24] In New Jersey, also, the trend of the mass of the Archæan has more easting according to Prof. G. H. Cook, as brought out in his New Jersey Geological Report (1868), than the strike of its beds, the former being about northeast and the latter north-northeast.

of the vertical row of pores in the ambulacral area into the arcs of three or four pairs of pores, and to the specialization of the actinal and abactinal systems.

In the Arbaciadæ the young stages are remarkable for the prominent sculpture of the test, for the flattened spines, for their simple poriferous zone, for their actinal system, and for their genital ring. The anal plates appear before the genital ring.

In the Echinometradæ the young thus far observed are characterized by the small number of their primary tubercles, the large size of the spines, the simple vertical row of pores, the closing of the anal ring by a single plate, and the turban-shaped outline of the test. Little by little, the test loses with increasing age this Cidaris-like character; it reminds us, from the increase in the number of its plates, more of Hemicidaris; then, with their still greater increase, of the Pseudodiadematidæ; and, finally, of the Echinometradæ proper. The spines, following *pari passu*, the changes of the test, lose little by little their fantastic embryonic, or rather Cidaris-like appearance, and become more solid and shorter, till they finally assume the delicately fluted structure characteristic of the Echinometradæ. The vertical poriferous zone is first changed into a series of connected vertical arcs, which become disjointed, and form, with increasing age, the independent arcs of pores, composed of three or more pairs of pores, of the Echinometradæ.

In the Echinidæ proper we find in the young stages the same unbroken vertical line of pores, which gradually becomes changed to the characteristic generic types. We find, as in the Echinometradæ, an anal system closed with a single plate, and an abactinal system separating in somewhat more advanced stages from the coronal plates of the test. This is as yet made up of a comparatively small number of plates, carrying but few large primary tubercles, with fantastically shaped spines entirely out of proportion to the test, but which, little by little, with the increase of the number of coronal plates, the addition of primary tubercles, and their proportional decrease in size, assume more and more the structure of the genus to which the young belongs. The original anal plate is gradually lost sight of from the increase in number of the plates covering the anal system, and it is only among the Temnopleuridæ that this anal plate remains more or less prominent in the adult. In the Salenidæ, of which we know as yet nothing of the development, this embryonic plate remains permanently a prominent structural feature of the apical system.*

* The young of the following genera have served as a basis for the preceding analysis of the embryonic stages of the Desmosticha: Cidaris, Dorocidaris, Goniocidaris, Arbacia, Podocidaris, Strongylocentrotus, Echinometra, Echinus, Toxopneustes, Hipponoë, Temnopleurus, Temnechinus, and Trigonocidaris.

Among the Clypeastroids the changes of form they undergo during growth are most instructive. We have in the young Fibularinæ an ovoid test, a small number of coronal plates surmounted by few and large primary tubercles, supporting proportionally equally large primary radioles, simple rectilinear poriferous zones, no petaloid ambulacra,—in fact, scarcely one of the features we are accustomed to associate with the Clypeastroids is as yet prominently developed. But rapidly, with increasing size, the number of primary tubercles increases, the spines lose their disproportionate size, the pores of the abactinal region become crowded and elongate, and a rudimentary petal is formed. The test becomes more flattened, the coronal plates increase in number, and it would be impossible to recognize in the young Echinocyamus, for instance, the adult of the Cidaris-like or Echinometra-like stages of the Sea-urchin, had we not traced them step by step. Most interesting, also, is it to follow the migrations of the anal system, which, to a certain extent, may be said to retain the embryonic features of the early stages of all Echinoderm embryos, in being placed in more or less close proximity to the actinostome. What has taken place in the growth of the young Echinocyamus is practically repeated for all the families of Clypeastroids; a young Echinarachnius, or Mellita, or Encope, or a Clypeaster proper, resembles at first more an Echinometra than a Clypeastroid; they all have simple poriferous zones and spines and tubercles out of all proportion to the size of the test.*

When we come to the development of the Spatangoids, we find their younger stages also differing greatly from the adult. Among the Nucleolidæ, for instance, the young stages have as yet no petals, but only simple rectilinear poriferous zones. They are elliptical with a high test, with a single large primary tubercle for each plate, and a simple elliptical actinostome, without any trace of the typical bourrelets and phyllodes so characteristic of this family. Very early, however, this condition of things is changed, the test soon becomes more flattened, the petals begin to form as they do in the Clypeastroids, and we can soon trace the rudiments of the peculiar bourrelets characteristic of the family, accompanied by a rapid increase in the number of tubercles and in that of the coronal plates.

Among the Spatangidæ some are remarkable in their adult condition for their labiate actinostome, for the great development of the petals, for the presence of fascioles surrounding certain definite areas, for the small size of the tubercles, the general uniformity in the spines of the test, and the specialization of their anterior and posterior regions. On examining the

* Among the Clypeastroids I have examined the young of Echinocyamus, Fibularia, Mellita, Laganum, Echinarachnius, Encope, Clypeaster, and Echinanthus.

young stages of this group of Spatangoids, not one of these structural features is as yet developed. The actinostome is simple, the poriferous zone has the same simple structure from the actinostome to the apex, the primary tubercles are large, few in number, surrounded by spines which would more readily pass as the spines of Cidaridæ than of Spatangoids. The fascioles are either very indistinctly indicated, or else the special lines have not as yet made their appearance; the ambulacral suckers of the anterior zones are as large and prominent as those of the young stages of any of the regular Echini. It is only little by little, with advancing age, that we begin to see signs of the specialization of the anterior and posterior parts of the test, that we find the characteristic anal or lateral fascioles making their appearance, only with increasing size that the spines lose their Cidaris-like appearance, that the petals begin to be formed, and that the simple actinostome develops a prominent posterior lip. In the genus Hemiaster, the young stages are specially interesting, as long before the appearance of the petals, while the poriferous zone is still simple, the total separation of the bivium and of the trivium of the ambulacral system, so characteristic of the earliest Spatangoids (the Dysasteridæ), is very apparent.*

From this rapid sketch of the changes of growth in the principal families of the recent Echini we can now indicate the transformation of a more general character through which the groups as a whole pass.

In the first place, while still in the Pluteus all the young Echini are remarkable for the small number of coronal plates, and for the absence of any separation between the actinal and abactinal systems and the test proper. They all further agree in the large size of the primary spines of the test, whether it be the young of a Cidaris, an Arbacia, an Echinus, a Clypeaster, or a Spatangoid. They all in their youngest stages have simple vertical ambulacral zones; beyond this, we find as changes characteristic of some of the Desmosticha, the specialization of the actinal system from the coronal plates, the formation of an anal system, the rapid increase in the number of the coronal plates, with a corresponding increase in the number of the spines and a proportional reduction of their size, the formation of an abactinal ring, and the change of the simple vertical poriferous zone into one composed of independent arcs.

In the Spatangoids and Clypeastroids we find common to both groups the shifting of the anal system to its definite place, the modifications of the abactinal part of the simple ambulacral

* For this sketch of the embryology of the Petalosticha I have examined the young of Echinolampas, Echinoneus, Echinocardium, Brissopsis, Agassizia, Spatangus, Brissus, and Hemiaster.

system in order to become petaloid, and the gradual change of the elliptical ovoid test of the young to the characteristic generic test, accompanied by the rapid increase in the number of the primary tubercles and spines. Finally limited to the Spatangoids are the changes they undergo in the transformation of the simple actinostome to a labiate one, the specialization of the anterior and posterior parts of the test, and the definite formation of the fascioles.

Comparing this embryonic development with the paleontological one, we find a remarkable similarity in both, and in a general way there seems to be a parallelism in the appearance of the fossil genera and the successive stages of the development of the Echini as we have traced it.

We find that the earlier regular Echini all have more or less a Cidaris-like look,—that is, they are Echini with few coronal plates, large primary tubercles, with radioles of a corresponding size; that it is only somewhat later that the Diademopsidæ make their appearance, which, in their turn, correspond within certain limits to the modifications we have traced in the growth of the young Diadematidæ and Arbaciadæ. The separation of the actinal system from the coronal plates has been effected. The poriferous zone has either become undulating, or forms somewhat indefinite open arcs; we find in all the genera of this group a larger number of coronal plates, more numerous primaries, the granules of the Cidaridæ replaced by secondaries and miliaries, and traces of a Hemicidaris-like stage in the size of the actinal ambulacral tubercles.

Comparing in the same way the paleontological development of the Echinidæ proper, we find that, on the whole, they agree well with the changes of growth we can still follow to-day in their representatives, and that, as we approach nearer the present epoch, the fossil genera more and more assume the structural features which we find developed last among the Echinidæ of the present day. Very much in the same manner as a young Echinus develops, they lose, little by little, first their Cidaridian affinities, which become more and more indefinite, next their Diadematidian affinities, if I may so call the young stages to which they are most closely allied, and, finally, with the increase in the number of the coronal plates, the great numerical development of the primary tubercles and spines, and that of the secondaries and miliaries which we can trace in the fossil Echini of the Tertiaries, we pass insensibly into the generic types characteristic of the present day.

Although we know nothing of the embryology of the Salenidæ, yet, like the Cidaridæ, they have in a great measure remained a persistent type, the modifications of the group being all in the same direction as those noticed in the other Desmos-

ticha; a greater number of coronal plates, the development of secondaries and miliaries combined with a specialization of the actinal system not found in the Cidaridæ.

An examination of the succession of the Echinoconidæ shows but little modification from the earliest types; the changes, however, are similar to those undergone by the Clypeastroids and Petalosticha, though they do not extend to modifications of the poriferous zone, but are mainly changes in the actinostome and in the tuberculation. In fact, the group of Echinoconidæ seems to hold somewhat the same relation to the Clypeastroids which the Salenidæ hold to the Cidaridæ, and the earliest genus of the group (Pygaster) has remained, like Cidaris, a persistent type to the present day.

The earliest Clypeastroids are all forms which resemble the Fibularina and the genera following Echinocyamus and Fibularia; they are mainly characterized by the same changes which an Echinarachnius or a Mellita, for instance, undergoes as it passes from its Echinocyamus stage to the Laganum or Encope stage. The comparison is somewhat more complicated when we come to the Spatangoids. The comparison of the succession of genera in the different families, as traced in the Desmosticha and Clypeastroids, is made difficult from the persistency of the types preceding the Echinoneidæ and the Ananchytidæ, which have remained without important modifications from the time of the lower Cretaceous; previous to that time the modifications of the Cassidulidæ are found to agree with the changes which have been observed in the growth of Echinolampas. The early genera, like Pygurus, have many of the characteristics of the test of the young Echinolampas. The development of prominent bourrelets and of the floscelle and petals goes on side by side with that of genera in which the modification of the actinostome, of the test, and of the petals is far less rapid, one group retaining the Echinoneus features, the other culminating in the Echinolampas of the present day, and having likewise a persistent type, Echinobrissus, which has remained with its main structural features unchanged from the Jura to the present day. That is, we find genera of the Cassidulidæ which recall the early Echinoneus stage of Echinolampas, next the Caratomus stage, after which the floscelle, bourrelets, and petals of the group become more prominent features of the succeeding genera. Accompanying the persistent type Echinobrissus, genera appear in which either the bourrelets or petals have undergone modifications more extensive than those of the same parts in the genera of the Echinoneus or Caratomus type.

The earliest Spatangoids belong to the Dysasteridæ, apparently an aberrant group, but which, from the history of the

young Hemiaster, we now know to be a strictly embryonic type, which, while it thus has affinities with the true Spatangoids, still retains features of the Cassidulidæ in the mode of development of the actinostome and of the petals, as well as of the anal system. The genera following this group, Holaster and Toxaster, can be well compared, the one to the young stages of Spatangus proper before the appearance of the petals, when the ambulacra are flush with the test, and when its test is more or less ovoid, the other to a somewhat more advanced stage, when the petals have made their appearance as semi-petals. In both cases the actinostome has the simple structure characteristic of all the young Spatangoids. The changes we notice in the genera which follow them lead in the one case through very slight modifications of the abactinal system, of the anterior and posterior extremities of the test, to the Ananchytid-like Spatangoids of the present day, the Pourtalesiæ, the genus Holaster itself persisting till well into the middle of the Tertiary period; while on the other side we readily recognize in the Spatanginæ which follow Toxaster (a persistent type which has continued as Palæostoma to the present day) the genera which correspond to the young stages of such Spatangoids as Spatangus and Brissopsis of the present day, genera which, on the one hand, lead from Hemiaster (itself still represented in the present epoch), through stages such as Cyclaster, Peripneustes, Brissus, and Schizaster, and, on the other, through Micraster and the like, to the Spatangoids, in which the development of the anal plastron and fasciole performs an important part, while in the former group the development of the peripetalous fasciole and of the lateral fasciole can be followed. None of the genera of Petalosticha belonging to the other groups develop any fasciole in the sense of circumscribing a limited area of the test.

The comparison of the genera of Echini which have appeared since the Lias with the young stages of growth of the principal families of Echini, shows a most striking coincidence amounting almost to identity between the successive fossil genera and the various stages of growth. This identity can, however, not be traced exactly in the way in which it has usually been understood, while there undoubtedly exists in the genera which have appeared one after the other a gradual increase in certain families in the number of forms, and a constant approach in each succeeding formation, in the structure of the genera, to those of the present day. It is only in the accordance between some special points of structure of these genera and the young stages of the Echini of the present day that we can trace an agreement which, as we go further back in time, becomes more and more limited. We are either compelled to

seek for the origin of many structural features in types of which we have no record, or else we must attempt to find them existing potentially in groups where we had as yet not succeeded in tracing them. The parallelism we have traced does not extend to the structure as a whole. What we find is the appearance among the fossil genera of certain structural features giving to the particular stages we are comparing their characteristic aspect. Thus, in the succession of the fossil genera, when a structural feature has once made its appearance, it may either remain as a persistent structure, or it may become gradually modified in the succeeding genera of the same family, or it may appear in another family, associated with other more marked structural features which completely overshadow it. Take, for instance, among the Desmosticha the modifications of the poriferous zone of the actinal and abactinal systems of the coronal plates, of the ambulacral and interambulacral systems, the changes in the relative proportion of the primary tubercles, and the development of the secondaries. These are all structural features which are modified independently one of the other; we may find simultaneous development of these features in parallel lines, but a very different degree of development of any special feature in separate families.

This is as plainly shown in the embryological as in the paleontological development. In the Cidaridæ there is the minimum of specialization in these structural features. In the Diademopsidæ there is a greater range in the diversity of the structure of the poriferous zone and of the coronal plates, as well as of the actinal system. There is a still greater range among the Echinidæ, while among the Salenidæ the modifications, as compared to those of the Echinidæ and Diademopsidæ, are somewhat limited again, being restricted as far as relates to the poriferous zone and coronal plates, but specialized as far as the actinal system is concerned, and specially important with reference to the structure of the apical system. The special lines in which these modifications take place produce, of course, all possible combinations, yet they give us the key to the sudden appearance, as it were, of structural features of which the relationship must be sought in very distantly related groups. It is to this specialty in the paleontological development that we must trace, for instance, the Cidarid affinities of the Saleniæ, their papillæ, the existence of few large primary interambulacral tubercles, the structure of their apical system, and their large genital plates; while it is to their affinities with the Hemicidaridæ that we must refer the presence of the few larger primary ambulacral tubercles at the base of the ambulacral area, and by their Diademopsid and Echinid-

ian affinities that we explain the indented imbricated actinal system with the presence of a few genuine miliaries. But all the structural features which characterize the earliest types of the Desmosticha can in reality be traced, only in a somewhat rudimentary form, even in the Cidaridæ. The slight undulation of the closely packed, nearly vertical poriferous zone is the forerunner of the poriferous zone first separated into vertical arcs and then into independent arcs. The limitation in the number of the rows of granules in the ambulacral zone, and their increase in size, is the first trace of the appearance of the somewhat larger primary ambulacral tubercles of the Hemicidaridæ and Saleniæ. The existence of the smooth cylindrical spines of the abactinal region of the test naturally leads to similar spines covering the whole test in the other families of the Desmosticha. The difference existing in the plates covering the actinal system from those of the coronal plates leads to the great distinction between the structure of the actinal system and of the coronal plates in some of the Echinidæ.

Passing to the Clypeastridæ and Petalosticha, we trace a parallelism of the same kind, and readily follow in the successive genera of fossil Clypeastroids, but often in widely separated genera, the precise modifications which the poriferous zone has undergone as it first becomes known to us in Echinocyamus and Fibularia, and as we find it in the most complicated petaloid stage of the Clypeastroids of the present day. We readily trace the changes the test undergoes from its comparatively ovoid and swollen shape to assume first that of the less gibbous forms, next that of the Laganidæ, and finally of the flat Scutellidæ; while we trace in the Echinanthidæ the persistent structural features of some of the earliest Clypeastroids, together with an excessive modification of the poriferous zone. Likewise for the Echinoconidæ we trace mainly the slight modifications of the poriferous zone and of the coronal plates, and finally, when we come to the Spatangidæ we find no difficulty in tracing from the most Desmostichoid of the Spatangoid genera, the modifications of a test in which the ambulacral and interambulacral areas are made up of plates of nearly uniform size, in which the anterior and posterior extremities are barely specialized, to the most typical of the Ananchytidæ, in which the anterior and posterior extremities have developed the most opposite and extraordinary structural features. In a similar way we can trace among the fossil genera of different families the gradual development of the actinal plastron from its very earliest appearance as a modification of the posterior interambulacral area of the actinal side, or the growth of the posterior beak into an anal snout, the successive changes of the anal groove, the formation of the actinal labium, or the devel-

opment of the bourrelets and phyllodes from a simple circular actinostome, the gradual deepening of the slight anterior groove of some early Spatangoid to form the deeply sunken actinal groove. Equally well we can trace the modifications of the ambulacral system as it passes from the simple poriferous zones of the earlier Spatangoids to genera in which the petaliferous portion makes its appearance, and finally becomes the specialized structure of our recent Spatangoid genera, such as Schizaster, Moira, and the like. Finally, we can trace to a certain extent the development of the fascioles on one side from genera like Hemiaster, in which the peripetalous fasciole is prominent, to genera like Brissopsis, Brissus, and the like, of the present day; on the other, perhaps, or in both combined, the formation of a lateral and anal fasciole from genera like Micraster in Spatangus and Agassizia. Thus we must, on the same theory of the independent modifications of special structural features, trace the many and complicated affinities which so constantly strike us in making comparative studies, and which render it impossible for us to express the manifold affinities we notice, without taking up separately each special structure. Any attempt to take up a combination of characters, or a system of combinations, is sure to lead us to indefinite problems far beyond our power to grasp.

In the oldest fossil Clypeastroids and Petalosticha, as well as in the Desmosticha, we also find the potential expression of the greater number of the modifications subsequently carried out in genera of later date. The semipetaloid structure of some of the earlier genera of Spatangoids, the slight modifications of some of the plates of the actinal side near the actinostome, are the precursors, the one of the highly complicated petaloid ambulacra of the recent Spatangoids, the other of the actinal plastron, leading as it does also to the important differences subsequently developed in the anterior and posterior extremities of the test, as well as to the modifications which lead to the existence of a highly labiate actinostome. The appearance of a few miliaries near the actinostome constitutes the first rudimentary bourrelets.

Going back now to the Palæchinidæ, the earliest representatives of the Echini in palæozoic times, without any attempt to trace the descent of any special type from them, we may perhaps find some clew to the probable modifications of their principal structural features preparatory to their gradual disappearance. In the structure of the coronal plates, the specialization of the actinal and abactinal systems, the conditions of the ambulacral system, we must compare them to stages in the embryonic development of our recent Echini with which we find no analogues in the fossil Echini of the Lias and the sub-

sequent formations. In order to make our parallelism, we must go back to a stage in the embryonic history of the young Echini in which the distinction to be made between the ambulacral and interambulacral systems is very indefinite, in which the apical system is, it is true, specialized, but in which the actinal system remains practically a part of the coronal system. But here the comparison ceases, and, although we can trace in the paleontological development of such types as Archæocidaris or Bothriocidaris modifications which would lead us without great difficulty, on the one side to the Cidaridæ, and on the other to the Echinothuriæ and Diadematidæ of the present day, we cannot fail to see most definite indications in some of the structural features of the Palæchinidæ of characteristics which we have been accustomed to associate with higher groups. The minute tuberculation, for instance, of the Clypeastroids and Spatangoids, already existing in the Melonitidæ, the genital ring, and anal system, are quite as much Echinid as Cidarid. The polyporous genera of the group represent to a certain extent the polypori of the regular Echini, and the lapping of the actinal plates of the Cidaridæ and of the coronal plates in some of the Diadematidæ, as well as the existence of such genera as Tetracidaris, of four interambulacral plates in Astropyga, and of a large number of ambulacral plates in some of the recent Echinometradæ, all these are Palæchinid characters which we can explain on the theory of the independent development of the structural features of which they are modifications. We should, however, remember, that the existence of a large number of coronal plates, especially interambulacral plates, in the Palæchinidæ, is a mere vegetative character, which they hold in common with all the Crinoids,—a character which is reduced to a minimum among the Holothurians, and still persists in full force among the Pentacrini of the present day, as well as the Astrophytidæ and Echinidæ.

It would lead me too far to institute the same comparison between the embryonic stages of the different orders of Echinoderms and their earliest fossil representatives. We may, however, in a very general way, state that we know the earliest embryonic stages of the orders of Echinoderms of to-day, which, with the exception of the Blastoidea and Cystideans, are identical with the fossil orders, and that as far as we know they all begin at a stage where it would be impossible to distinguish a Sea-urchin from a Star-fish, or an Ophiuran, or a Crinoid, or an Holothurian,—a stage in which the test, calyx, abactinal and ambulacral systems are reduced to a minimum. From this identical origin there is developed at the present day, in a comparatively short period of time, either a Star-fish, a Sea-urchin, or a Crinoid; and if we have been able success-

fully to compare, in the development of typical structures, the embryonic stages of the young Echini with their development in the fossil genera, we may fairly assume that the same process is applicable when instituting the comparison within the different limits of the orders, but with the same restrictions. That is, if we wish to form some idea of the probable course of transformations which the earliest Echinoderms have undergone to lead us to those of the present day, we are justified in seeking for our earliest representatives of the orders such Echinoderms as resemble the early stages of our embryos, and in following, for them as for the Echini, the modifications of typical structures. These we shall have every reason to expect to find repeated in the fossils of later periods, and, going back a step further, we may perhaps get an indefinite glimpse of that first Echinodermal stage which should combine the structural features common to all the earliest stages of our Echinoderm embryos.

And yet, among the fossil Echinoderms of the oldest periods, we have not as yet discovered this earliest type from which we could derive either the Star-fishes, Ophiurans, Sea-urchins, or Holothurians. With the exception of the latter, which we can leave out of the question at present, we find all the orders of Echinoderms appearing at the same time. But while this is the case, one of the groups attained in these earliest days a prominence which it gradually loses with the corresponding development of the Star-fishes, Ophiurans, and Sea-urchins, it has steadily declined in importance; it is a type of Crinoids, the Cystideans which culminated during Paleozoic times, and completely disappeared long before the present day. If we compare the early types of Cystideans to the typical embryonic Echinodermal type of the present day, we find they have a general resemblance, and that the Cystideans and Blastoids represent among the fossil Echinoderms the nearest approach we have yet discovered to this imaginary prototype of Echinoderms.

This may not seem a very satisfactory result to have attained. It certainly has been shown to be an impossibility to trace in the paleontological succession of the Echini anything like a sequence of genera. No direct filiation can be shown to exist, and yet the very existence of persistent types, not only among Echinoderms, but in every group of marine animals, genera which have continued to exist without interruption from the earliest epochs at which they occur to the present day, would prove conclusively that at any rate some groups among the marine animals of the present day are the direct descendants of those of the earliest geological periods. When we come to types which have not continued as long, but yet

which have continued through two or three great periods, we must likewise accord to their latest representatives a direct descent from the older. The very fact that the ocean basins date back to the earliest geological periods, and have afforded to the marine animals the conditions most favorable to an unbroken continuity under slightly varying circumstances, probably accounts for the great range in time during which many genera of Echini have existed. If we examine the interlacing in the succession of the genera characteristic of later geological epochs, we find it an impossibility to deny their continuity from the time of the Lias to the present day. The Cidaris of the Lias and the Rhabdocidaris of the Jura are the ancestors of the Cidaris of to-day. The Saleniæ of the lower Chalk are those of the Saleniæ of to-day. Acrosalenia extends from the Lias to the lower Cretaceous, with a number of recent genera, which begin at the Eocene. The Pygaster of to-day dates back to the Lias; Echinocyamus and Fibularia commence with the Chalk. Pyrina extends from the lower Jura through the Eocene. The Echinobrissus of to-day dates back to the Jura. Holaster lived from the lower Chalk to the Miocene, and the Hemiaster of to-day cannot be distinguished from the Hemiaster of the lower Cretaceous.

Such descent we can trace, and trace as confidently as we trace a part of the population of North America of to-day as the descendants of some portion of the population of the beginning of this century. But we can go no further with confidence, and bold indeed would he be who would attempt even in a single State to trace the genealogy of the inhabitants from those of ten years before. We had better acknowledge our inability to go beyond a certain point; anything beyond the general parallelism I have attempted to trace, which in no way invalidates the other proposition, we must recognize as hopeless.

But in spite of the limits which have been assigned to this general parallelism, it still remains an all-essential factor in elucidating the history of paleontological development, and its importance has but recently been fully appreciated. For, while the fossil remains may give us a strong presumptive evidence of the gradual passage of one type to another, we can only imagine this modification to take place by a process similar to that which brings about the modifications due to different stages of growth,—the former taking place in what may practically be considered as infinite time when compared to the short life history which has given us as it were a *résumé* of the paleontological development. We may well pause to reflect that in the two modes of development we find the same periods of rapid modifications occurring at certain stages of

growth or of historic development, repeating in a different direction the same phases. Does it then pass the limits of analogy to assume that the changes we see taking place under our own eyes in a comparatively short space of time,—changes which extend from stages representing perhaps the original type of the group to their most complicated structures,—may, perhaps, in the larger field of paleontological development, not have required the infinite time we are in the habit of asking for them?

Paleontologists have not been slow in following out this suggestive track, and those who have been anatomists and embryologists besides have not only entered into most interesting speculations regarding the origin of certain groups, but they have carried on the process still futher, and have given us genealogical trees where we may, in the twigs and branches and main limbs and trunk, trace the complete filiation of a group as we know it to-day, and as it must theoretically have existed at various times to its very beginning. While we cannot but admire the boldness and ingenuity of these speculations upon genetic connection so recklessly launched during the last fifteen years, we find that with but few exceptions there is little to recommend in reconstructions which shoot so wide of the facts as far as they are known, and seem so readily to ignore them. The moment we leave out of sight the actual succession of the fossils and the ascertainable facts of postembryonic development, to reconstruct our genealogy, we are building in the air. Ordinarily, the twigs of any genealogical tree have only a semblance of truth: they lead us to branchlets having but a slight trace of probability, to branches where the imagination plays an important part, to main limbs where it is finally allowed full play, in order to solve with the trunk, to the satisfaction of the writer at least, the riddle of the origin of the group. It seems hardly credible that a school which boasts for its very creed a belief in nothing which is not warranted by common sense should descend to such trifling.

The time for genealogical trees is passed; its futility can, perhaps, best be shown by a simple calculation, which will point out at a glance what these scientific arboriculturists are attempting. Let us take, for instance, the ten most characteristic features of Echini. The number of possible combinations which can be produced from them is so great that it would take no less than twenty years, at the rate of one new combination a minute for ten hours a day, to pass them in review. Remembering now that each one of these points of structure is itself undergoing constant modifications, we may get some idea of the nature of the problem we are attempting to solve, when seeking to trace the genealogy as understood by the makers of

genealogical trees. On the other hand, in spite of the millions of possible combinations which these ten characters may assume when affecting not simply a single combination, but all the combinations which might arise from their extending over several hundred species, we yet find that the combinations which actually exist—those which leave their traces as fossils—fall immensely short of the possible number. We have, as I have stated, not more than twenty-three hundred species actually representing for the Echini the results of these endless combinations. Is it astonishing, therefore, that we should fail to discover the sequence of the genera, even if the genera, as is so often the case, represents, as it were, fixed embryonic stages of some Sea-urchin of the present day? In fact, does not the very history of the fossils themselves show that we cannot expect this? Each fossil species, during its development, must have passed through stages analogous to those gone through by the Echini of the present day. Each one of these stages at every moment represents one of the possible combinations, and those which are actually preserved correspond only to the particular period and the special combination which any Sea-urchin has reached. These stages are the true missing links, which we can no more expect to find preserved than we can expect to find a record of the actual embryonic development of the species of the present day without direct observation at the time. The actual number of species in any one group must always fall far short of the possible number, and for this reason it is out of the question for us to attempt the solution of the problem of derivation, or to hope for any solution beyond one within the most indefinite limits of correctness. If, when we take one of the most limited of the groups of the animal kingdom, we find ourselves engaged in a hopeless task, what must be the prospect should we attack the problem of other classes or groups of the animal kingdom, where the species run into the thousands, while they number only tens in the case we have attempted to follow out? Shall we say "ignorabimus" or "impavidi progrediamus" and valiantly chase a phantom we can never hope to seize?

ART. XLI.—*Notice of the remarkable Marine Fauna occupying the outer banks off the southern coast of New England;* by A. E. VERRILL. (Brief Contributions to Zoology from the Museum of Yale College: No. XLVII.)

DURING the present season the headquarters of the U. S. Fish Commission, Professor S. F. Baird, Commissioner, were at Newport, R. I. The investigation of the marine invertebrate fauna of the region was very effectually carried out by the large party employed under the general direction of the writer. Large collections were made in the shallower waters of the coast, both at the surface and along the shores, as well as by dredging and trawling. The new steamer "Fish Hawk," of 480 tons, built last year specially for the Fish Commission, and fitted up with suitable appliances for its scientific work, was employed in the trawling and dredging. It was commanded by Lieut. Z. L. Tanner, U. S. N., who was also in command of the "Speedwell" last season. The writer had, as associates and assistants, for the invertebrata, Mr. Richard Rathbun, Mr. Sanderson Smith, Mr. J. H. Emerton (as artist), Mr. B. F. Koons, Mr. E. A. Andrews, Mr. Charles Bent, Mr. N. P. Scudder. Capt. H. C. Chester, as usual, had charge of the apparatus. Wire rope was very satisfactorily used for the dredging and trawling. In September and October, three very successful trips were made to the outer banks, or the region where the wide area of shallow water more rapidly falls off into the deep water of the Atlantic basin.

The first of these trips was made Sept. 3d to 5th, south of Martha's Vineyard, about 75 to 80 miles (stations 865 to 872) where the depth was from 65 to 192 fathoms. The bottom was mostly fine compact sand, with some mud, and with a large percentage of Foraminifera. The second trip was made Sept. 12th to 14th, nearly south from Newport, 90 to 105 miles, where the depth was from 85 to 325 fathoms (stations 873 to 881). The third trip, Oct. 1st to 3d, was to the same region, but somewhat farther west and south, and in deeper water, (stations 891 to 895). At all these stations, except 867, a large beam-trawl was used; at 867 a heavy "rake-dredge," of a new form, was used with good success.

The temperature determinations, owing to the violent motions of the steamer, are unreliable at stations 865 to 872. At stations 873–878 the bottom temperature was usually 51° to 53° F.; at 879–881, it was 42° to 43° F.; at 893, 894, it was 40° F.

All these stations are located in the region designated on the charts as "Block Island Soundings," and nearly all proved to be exceedingly rich in animal life, the vast abundance of individuals of many of the species taken being almost as surprising

as the great number and variety of the species themselves. Crustacea, Mollusca, Annelids and Echinoderms were the most numerous. The very large quantity of specimens obtained on these three trips has, as yet, been only partially examined, but enough has already been done to prove this region to be altogether the richest and most remarkable dredging ground ever discovered on our coast.

Dredging stations on the outer bank, in 1880.

No.	Locality. Lat.				Long.				Depth, Fathoms.	Nature of bottom.
865	40°	05′		N.	70°	23′		W.	65	Fine compact sand with some mud.
866	40	05	18″	N.	70	22	18″	W.	65	" " "
867	40	05	42	N.	70	22	06	W.	64	" " "
868	40	01	42	N.	70	22	30	W.	162	" " "
869	40	02	18	N.	70	23	06	W.	192	Mud and fine sand, soft.
870	40	02	36	N.	70	22	58	W.	155	Fine sand with some mud.
871	40	02	54	N.	70	23	40	W.	115	" "
872	40	05	39	N.	70	23	52	W.	86	Shells and sponges.
873	40	02		N.	70	57		W.	100	Fine sand and mud.
874	40			N.	70	57		W.	85	" "
875	39	57		N.	70	57	30	W.	126	" "
876	39	57		N.	70	56		W.	120	" "
877	39	56		N.	70	54	18	W.	126	" "
878	39	55		N.	70	54	15	W.	142½	" "
879	39	49	30	N.	70	54		W.	225	" "
880	39	48	30	N.	70	54		W.	252	Mud and fine sand.
881	Somewhat farther south.								325	Mud. Trawl partially fouled.
891	39	46		N.	71	10		W.	±500	Mud and fine sand.
892	39	46		N.	71	05		W.	487	Mud, fine sand, small stones.
893	39	52	20	N.	70	58		W.	372	" " "
894	39	53		N.	70	58	30	W.	365	" " "
895	39	56	30	N.	70	59	45	W.	238	" " "

MOLLUSCA.—Of Mollusca, about 175 species were taken. Of these, 120 species were not before known to occur on the southern coast of New England; about 65 species are additions to the American fauna; of these about 30 species are, apparently, undescribed. The known species now added to our fauna have mostly been described by G. O. Sars, Jeffreys, and others, from the deep waters of the European coast and the Mediterranean.

List of Mollusca new to the New England coast.

[Those with *n* prefixed were previously known from off Nova Scotia or farther north. Various undetermined species are not included.]

Heteroteuthis tenera V., nov.
Calliteuthis reversa V., gen. and sp. nov.
Alloposus mollis V., sp. and gen. nov.
Argonauta Argo Linné.
Taranis Morchii Sars.
n.Bela tenuicostata Sars.
Pleurotoma Agassizii V. & S., nov.
Pleurotoma Carpenteri V. & S., nov.
Marginella roscida Rav.?
n.Neptunea propinqua (Alder).
Tritonofusus latericeus (Möll.) Morch.
Lamellaria pellucida V., nov.
n.Lovenella Whiteavesii Verrill, nov.
Cingula turgida (Jeff.)
n.Cingula Jan-Mayehi (Friele) V.
Lepetella tubicola V. & S., gen. and sp. nov.
Scalaria Dalliana V. & S., nov.
Scalaria (fragile).
Scalaria Pourtalesii V. & S., nov.
Solarium, sp. (sharply carinated).
Aclis Walleri J.
Calliostoma Bairdii V. & S., nov.

Margarita regalis V. & S., nov.
Margarita lamellosa V. & S., nov.
Turbonilla Rathbuni V. & S., nov.
Turbonilla formosa V. & S., nov.
Eulima intermedia Cantr.
Eulima distorta Desh.
n.Philine Finmarchica Sars.
Philine amabilis V., nov.
Amphisphyra globosa Lovén.
Diaphana gemma V., nov.
Diaphana nitidula (Lovén).
Pleurobranchæa tarda V., nov.
Doris complanata V., nov.
Carinaria Atlantica Ad. & R.
Clio pyramidata Linné.
Balantium.
Cymbulia calceola V., nov.
Spirialis retroversus (Flem.)
Cavolina longirostris (Les.)
Cavolina uncinata (Rang.)
Siphonentalis Lofotensis Sars.
Cadulus Pandionis V. & S., nov.
Cadulus Jeffreysii (Monteros.)
Cadulus propinquus G. O. Sars.
Poromya rotundata Jeff.
Nœra rostrata (Speng.) Lovén.
Nœra costellata?
Nœra jugosa S. Wood.
Pecchiolia abyssicola Sars.
n.Kennerlia glacialis (Leach) Carp.
Cardium, sp. nov. (cancellated.)
Loripes lens V. & S., nov.
Cryptodon ferruginosus (Forbes).
n. Yoldia frigida Torell.
Leda unca Gould.
Limopsis cristata Jeff.?
Limopsis minuta (Phil.)
Modiola polita V. & S., nov.
Avicula hirundo? var. *nitida* V.
n.Pecten vitreus (Gmel.) Wood.
n.Pecten Hoskynsi Forbes, var. *pustulosus* V.
Pecten fenestratus Forbes?
Limæa subovata (Jeffreys) Monteros.

List of Mollusca new to the southern coast of New England, but previously known to me from the northern coast.

Rossia sublevis Verrill.
Octopus Bairdii Verrill.
Admete Couthouyi Jay(=*A. viridula* Gld.)
Bela exarata (Möll.) Ad.
Bela impressa Morch (S. 814).
Bela violacea (Migh.) Ad. (S. 812).
Neptunea decemcostata (Say) Ad.
Neptunea Stimpsoni (Morch), (= *Fusus Islandicus* Gld.)
Anachis costulata (Cant.) (= *Columbella Haliœeti* Jeff.)
Lunatia Grönlandica (Möll.) Ad.
Lunatia nana (Möll.) (S. 812, 814).
Torellia vestita Jeff.
Aporrhais occidentalis Beck.
Colliostoma occidentale (Migh.) Dall.
Puncturella noachina (L.) Lowe.
Turbonilla nivea (St.) Ad.
Odostomia modesta Stimp.
Ringicula nitida V.
Scaphander puncto-striata (Migh.) Ad.
Amphisphyra pellucida (Brown) Lovén.
Cylichna occulta (Migh.) Ad.
Siphonodentalium vitreum Sars.
Dentalium occidentale Stimp. (=*D. abyssorum* Sars.)
Teredo megotara Hanl.
Saxicava Norvegica (Speng.) Woodw.
Cyrtodaria siliqua (Speng.) Woodw.
Nœra obesa Lovén (=*N. pellucida* St.)
Nœra arctica Lovén.
Nœra glacialis G. O. Sars.
Poromya granulata (Nyst.) F. and Han.
Thracia myopsis Möll.
Cardium Islandicum Linné.
Astarte crenata Gray (=*A. lens* St.)
Nucula delphinodonta Mighels.
Yoldia thraciformis (Storer) Stimp.
Yoldia expansa Jeff. (?)
Arca glacialis Gray.
Arca pectunculoides Sc., (? var. of last).
Crenella decussata (Mont.) Macg.
Dacrydium vitreum (Möll.) Sars.
Pecten Islandicus Müller.
Terebratulina septentrionalis (Couth.)

*Descriptions of new species included in the preceding lists.**

Heteroteuthis tenera Verrill, sp. nov.

Body small, rather short, scarcely twice as long as broad, obtuse. Fins thin, rounded, relatively very large, length about two-thirds that of the body, longer than broad, the anterior edge extending forward beyond the mantle. Arms

* In an article in the Proceedings of the National Museum, detailed descriptions of the new species will be given. Therefore only the more diagnostic characters are given here.

slender; in the male the left dorsal arm is hectocotylized, being broader than its mate, with four rows of minute suckers, while on the right one, and in the female on both, there are two regular rows of larger suckers. Lateral and ventral arms have the middle suckers (eight to ten) much larger than the distal and proximal ones; in the male this disparity becomes very marked, the larger suckers being eight or ten times as large as the proximal ones. These suckers are deep, laterally attached, with small opening and smooth rim. Tentacular arms long, slender, with broader club; suckers numerous, unequal, in about eight rows, those in the upper rows much larger than the others, with denticulated rims. Color translucent white with large purple chromatophores, which are also found on the inner surfaces of the arms and between the suckers. Length of body 25 to 40^{mm}. More or less abundant at all the stations, from 865 to 880, inclusive. About 200 specimens were taken.

Calliteuthis Verrill, gen. nov.

Form much as in *Histioteuthis*, but without any web between the arms. Body short, tapering to a free tip; fins small, united behind. Siphon united to head by two dorsal bands; an internal valve. Mantle connected to sides of siphon by lateral elongated cartilages and grooves. Arms long, free; suckers in two rows, largest on middle of lateral and dorsal arms. Eyes large, with oval openings. Buccal membrane simple, sac-like.

Calliteuthis reversa Verrill, sp. nov.

Arms long, tapering, the lateral pairs equal; the dorsal and ventral about equal, somewhat shorter than laterals; tentacular arms slender, compressed, (the ends absent). Fins small, thin, transversely rhomboidal, white. Color reddish brown; the ventral surface of body, head and arms covered with large, rounded verrucæ; their center or anterior half pale, the border or posterior half dark purplish brown; upper surface of body with much fewer and smaller scattered verrucæ; a circle of same around the eyes; inner surface of arms and buccal membranes chocolate-brown. Total length, 133^{mm}; to base of arms, 67; of mantle, 51; of fin, 17; breadth of fins, 24; of body, 20; diameter of eye-ball, 16^{mm}. Station 894.

Alloposus Verrill, gen. nov.

Allied to *Philonexis* and *Tremoctopus*. Body thick and soft, smooth; arms all (in the male only seven) united by a web extending nearly to the ends, the length of the arms decreasing from the dorsal to ventral ones; suckers sessile, simple, in two rows; mantle united firmly to the head by a ventral and two lateral *commissures*, the former placed in the median line, at the base of the siphon, and by a broad dorsal band; free end of the

siphon short, well forward. In the male the right arm of the third pair is hectocotylized, and developed in a sac, in front of the right eye; as found in the sac, it is curled up, and has two rows of suckers; the groove along its edge is fringed; near the end, the groove connects with a rounded, obliquely placed, lateral, concave lobe, with interior plications; the terminal portion of the arm is a lanceolate thickened process, with ridges on the inner surface. The permanent attachment of the mantle and neck, by means of commissures, is a very distinctive character.

Alloposus mollis Verrill, sp. nov.

Body stout, ovate, very soft and flabby. Head large, as broad as the body; eyes large, their openings small. Arms rather stout, not very long, webbed nearly to the ends, the dorsal 60^{mm} longer than the ventral arms; suckers large, simple, in two alternating rows. Color deep purplish brown, with a more or less distinctly spotted appearance. Length, total, 160; of body, to base of arms, 90; of mantle beneath, 50; of dorsal arms, 70; breadth of body, 70^{mm}. The sexes scarcely differ in size. Stations 880, in 225 fathoms, (2 ♂, 1 ♀), 892, 893, 895.

Cymbulia calceola Verrill, sp. nov.

Test thick, transparent, broad-ovate, rounded at both ends, covered, above and below, with low rounded verrucæ; aperture large, with simple unarmed edges. Animal pale pink, with brown nucleus; fins very large, connate, broadly rounded. Length of test, ·40^{mm}; breadth, ·20. Stations 865 to 872, (near surface), common.

Pleurotoma Agassizii Verrill and Smith,* sp. nov.

Shell large and handsomely sculptured; whorls eight, convex, shouldered, with about sixteen thick, rounded, oblique ribs, separated by concave interspaces; the ribs do not extend above the shoulder, leaving a rather broad, flattened band, which is covered by raised revolving lines, more or less decussated by prominent lines of growth and slight riblets, running down from the suture; the revolving lines become stronger and more elevated below the shoulder, and cross the ribs as well as their intervals; toward the canal the ribs fade out and the revolving lines become still more prominent. Outer lip with a wide and rather deep rounded notch below the suture; below this it curves strongly forward, and recedes again at the canal, which is rather short, narrowed, and a little excurved. Columella smooth, curved, and obliquely

* Mr. Sanderson Smith has been associated with me, during the present and two preceding seasons, in working up the testaceous mollusca. The species here briefly described under our joint names will be described, in detail, in a special article in the Proceedings of the National Museum.

narrowed at the canal. Aperture subovate, sinuous, rather large. Shell white, except the columella, which is stained with orange-brown. Length, 31; breadth, 14; length of aperture, 16; breadth, 6mm. Stations 865–880; 891, 892; 894; 895.

The animal has neither operculum nor eyes, and does not properly belong to *Pleurotoma* (restricted). It is, perhaps, most nearly related to *Pleurotomella* V. The uncini differ from all those figured by G. O. Sars, resembling most those of *Thesbia*. The basal appendage is large and oblique.

Pleurotoma Carpenteri Verrill and Smith, sp. nov.

Shell rather small, solid, slender; surface glossy. Whorls eight, somewhat convex, crossed by about twelve strong, elevated, flexuous, smooth, rounded longitudinal ribs, which extend entirely across the upper whorls, and on the body whorls from the suture to the middle, below which the surface is smooth; the interstices between the ribs are deeply concave, wider than the ribs, and perfectly smooth, except the faint lines of growth. Outer lip with a broad shallow notch, below the suture. Aperture rather small, ovate; canal short, narrow, straight; columella nearly straight. Color, pale brownish. Length, 7; breadth, 2·75mm. Stations 870–873.

Scalaria Pourtalesii Verrill and Smith, sp. nov.

Shell pure white, rather stout, with seven well-rounded whorls, crossed by about sixteen high, thin, lamellar, somewhat oblique ribs, which rise into acute angles or points just below the suture. Whorls scarcely united, except by the ribs, which often alternate on successive whorls. Interstices covered with fine revolving lines, not visible without a lens. Aperture round, with a broad, somewhat reflexed lip; umbilicus small, concealed behind the inner lip; no basal keel. Length, 17·5; breadth, 10; of aperture, 4mm. Stations 873, 874.

Scalaria Dalliana Verrill and Smith, sp. nov.

Shell smaller and much slenderer than the last, thin, delicate, bluish white. Whorls eleven, evenly rounded, with deeply indented sutures. Ribs about twenty, on the lower whorls, moderately high, thin, oblique, often with a small sharp denticle, just below the suture; they often alternate; interstices wider than the ribs, smooth, without distinct revolving lines. Aperture round with a reflexed lip, nearly even all around; umbilicus none. Length, 10·5; breadth, 3·5mm. Stations 869, 870, 871, 873, etc., not uncommon.

Lamellaria pellucida Verrill, sp. nov.

Animal yellowish brown mottled with darker, broad elliptical, swollen, without tubercles on the back. Shell ovate, with

oblique spire, delicate, transparent, smooth; aperture broad ovate, not showing the interior of the spire, except from an endwise view. Middle tooth of the odontophore with the basal portion oblong and truncated posteriorly, (not bilobed as in other species). Length, 12 to 16^{mm}, when living. Stations 870, 871, 872, several specimens, ♂ and ♀

Lepetella Verrill, gen. nov.

Shell small, smooth, oval or oblong, limpet-shaped, conical, with a simple sub-central apex, not spiral. Animal much as in *Lepeta*, but with distinct eyes. Odontophore tænioglossate, with seven regular rows of teeth.

Lepetella tubicola Verrill and Smith, sp. nov.

Shell thin, white, smooth, conical, with the apex acute and nearly central; aperture broad elliptical, oblong, or subcircular, usually more or less warped, owing to its habitat; edge thin and simple. Sculpture none, lines of growth slight, outer surface dull white; inner surface smooth, with the pallial markings faint. Length of largest specimens 3·75; breadth, 3; height, 2^{mm}. On inside of old tubes of *Hyalinœcia;* twenty-seven were taken from one tube. Stations, 869, 192 fath., and 894.

Lovenella Whiteavesii Verrill, sp. nov.

Shell slender, white, acute, allied to *L. metula.* Whorls nine or ten, flattened, with a prominent nodulous carina below the middle, a smaller one just below the suture, and another on the last whorl, in line with edge of lip, below this smooth; the whorls are crossed by numerous elevated, rounded, curved ribs. Columella much incurved above; canal excurved; outer lip with three angles. Length 4·5^{mm}; breadth 1·5^{mm}; one is considerably larger. Stations 891, 894; also Gulf St. Lawrence (Whiteaves).

Calliostoma Bairdii Verrill and Smith, sp. nov.

Shell large, strong, regularly conical, with a flattened base, no umbilicus, yellowish white or light yellow, with more or less numerous narrow, spiral bands of pale brown or dark brown, and with large squarish spots of bright rosey red on the spire. Whorls nine or ten, flattened, or concave, below the suture, which is not impressed. The last whorl has eight to ten conspicuous, raised, nodulous revolving ribs, of which three or four are much smaller and alternate with the larger ones; the strongest rib is just below the suture; interstices concave, brownish, glossy, obliquely striated by the lines of growth, and sometimes with subordinate, revolving, raised lines. The four principal ribs are continued on the upper whorls, but the intermediate ones gradually disappear on the middle whorls. The nodules

on the ribs are prominent, rounded and smooth, whitish, and extend to near the apex. Nuclear whorl smooth; next with three carinæ. Base with about twelve spiral, nodulous ribs with some intermediate, smaller ones; umbilical region slightly excavated, spirally. Columella strongly concave, terminating in an indistinct tooth. Animal yellowish with long tentacles, and with four long cirri on each side; eyes well developed. Dentition somewhat different from the typical species of the genus; there is no large lateral tooth, between the inner and outer series; outermost ones broad flat, curved. Operculum thin, circular, with many narrow whorls. Length, 32; breadth, 30; breadth of aperture, 15^{mm}. Taken alive at nearly all the stations, from 865 to 880, inclusive. A very handsome and showy species, having a tropical aspect.

Margarita regalis Verrill and Smith, sp. nov.

Shell rather large for the genus, thin and delicate, whitish, brilliantly iridescent or pearly, externally and internally, broad conical, turreted, wider than high, with a convex base, and deep umbilicus. Whorls seven, much flattened, with the suture scarcely impressed; the upper whorls are coronated by two, and the body whorl by three, revolving, strongly nodulous ribs, along which the conical, often acute nodules are very regularly arranged. The first of these rows of nodules is just below the suture; the second is separated from the first by a wide, flat, or slightly concave interspace; the third is not far from the second, and surrounds the periphery, usually corresponding with the line of the suture; the second and third are usually the most elevated; on the base there are five or six strong, rounded, revolving ribs, part of them usually somewhat nodulous, separated by deep, concave interspaces, rather wider than the ribs; one or two additional ones often appear in the umbilical opening, which is funnel-shaped and moderately large, but often partially obstructed by the reflexed edge of the inner lip. The interspaces between all the ribs are covered with close, slightly raised lines of growth, and usually with traces of a thin epidermis. Aperture somewhat quadrangular, large, lip thin. Animal with long tentacles and large black eyes; four large lateral cirri on each side, with a group of four or five small intermediate ones; snout with a broad, bilobed crescent-shaped expansion in front. Odontophore without a large lateral tooth between the inner and outer series, otherwise much like typical *Margaritæ*. Length, 14; breadth, 15^{mm}; often larger. Stations 865, 870, 871, 873, 880, 891–895, common.

Margarita lamellosa Verrill and Smith, sp. nov.

Shell small, fragile, conical, canaliculate, with a wide umbilicus. Whorls five, angulated and carinated below the middle,

swollen just below the suture, which lies in a deep channel; they are crossed, above the peripheral carina, by numerous elevated, thin, oblique ribs, which rise into lamellæ near the suture, where they join the carina forming small nodules; between the ribs are fine parallel lines of growth and sometimes a few fine revolving lines. Below the periphery, in line with the posterior edge of the lip, there is a smaller, plain, angular rib, and around the umbilicus there is a strong nodulose rib. Between these ribs, the base is covered with fine revolving lines. Within the umbilicus are radiating raised lines which cross two or three small revolving ribs. Aperture rounded, with angles corresponding to the ribs. Length, 3; breadth, 3^{mm}. Station 871, scarce.

Turbonilla Rathbuni Verrill and Smith, sp. nov.

Shell white, large for the genus, elevated, with twelve rather convex whorls, and impressed sutures. The whorls are slightly flattened and crossed by numerous slightly flexuous, elevated, smooth, even ribs, of which there are about thirty on the lower whorls; intervals about as wide as the ribs, concave, crossed by impressed revolving lines, of which there are eight or ten on the spire. Aperture somewhat oblong, with the lip a little prolonged and slightly effuse anteriorly. Columella nearly straight, smooth. Umbilicus none. Length, 13; breadth, 4^{mm}. Station 869, 192 fathoms, common; 894, 895.

Turbonilla formosa V. and S., sp. nov.

Shell white, lustrous, large, in form and size resembling the preceding; whorls twelve, somewhat flattened; aperture ovate, effuse in front; sculpture, strong rounded ribs, but without any revolving lines. Stations 891, 892.

Pleurobranchæa tarda V., sp. nov.

Body ovate, stout, swollen, strongly convex, yellowish brown, reticulated with dark brown. Gill plumose, at middle of right side, purple. Tentacles short, inrolled, obtuse. Proboscis large, purple. Odontophore large and broad, with 150 to 170 rows of teeth, no median tooth; teeth all similar, but gradually changing toward margins; inner ones narrow, lanceolate, curved, acute, with a stout denticle on the inner edge, near the end; outer teeth have the side denticle rudimentary. Length 30 to 40^{mm}. Common at stations 814, 865–880; 28 to 250 fathoms; over 200 specimens taken. One, 60^{mm} long, from station 895.

Philine amabilis V., sp. nov.

Shell very thin, diaphanous, delicate, and shining with bright iridescence; very large for the genus, and very open,

showing the interior of the spire, broad oblong, with rounded ends; outer lip evenly rounded posteriorly and scarcely projecting beyond the spire; apex occupied by a shallow pit. Sculpture, conspicuous wavy lines of growth, and microscopic wavy spiral striæ, over the whole surface. Length of shell, 15; breadth, 10^{mm}. Odontophore with a large hook-shaped inner lateral tooth, on each side, and a slender spiniform outer one. Gizzard large, with three calcareous plates. Station 876, several living specimens.

Diaphana (*Utriculus**) *gemma* V., sp. nov.

Shell white, rather solid, resembling, in size and form, *Cylichna occulta* (Migh.), but distinguished by having a small, distinct umbilicus, and also a narrow deep pit at the apex of the spire. Sculpture, a few distinct spiral lines at each end; middle region of shell smooth. Length, 4·2; breadth, 2·5^{mm}. Stations 871, 873.

Doris complanata V., sp. nov.

Body large, broad elliptical, depressed, pale brown to dusky brown, more or less mottled, back nearly smooth, with few minute verrucæ. Dorsal tentacles stout, clavate, with many crowded lamellæ, sheaths plain. Gills ten, large, bipinnate, brown, retractile into a large cavity. Oral tentacles free, ovate, tapered. Odontophore with 70 to 80 rows of lateral teeth, the outermost smallest: 22 to 24 inner lateral ones, on each side, sharp, hook-shaped, with two side lobes; those exterior to these, have obtuse, incurved, denticulate ends. Length, 50; breadth, 25^{mm}. Station 872, eight specimens.

Cadulus Pandionis V. and S., sp. nov.

Shell very large for the genus, white, transparent, very smooth and polished, shining, strongly curved, largest in front of the middle, with the aperture oblique; sculpture none. The shell is somewhat transversely elliptical in section, slightly gibbous and most swollen at about the anterior third, on the convex side; from this point gradually tapering to the slender posterior end, and to the mouth, which is slightly broader than high, and recedes considerably on the convex side of the shell, with a thin smooth margin. Posterior opening small, with a semicircular notch above and below. Length, 10; breadth, 2·25; breadth of aperture, 1·75; of anal aperture, ·40^{mm}. Stations 869–871, 873, 874, 876 (abundant), 877, 891.

* I here use *Diaphana* for the restricted genus *Utriculus*, as adopted by G. O. Sars. It is peculiar in lacking the odontophore. *Utriculus* is preöccupied by Schumacher (1817). Our "*Utriculus Gouldii*" is, in its gizzard and dentition, a true *Cylichna* and should be called *Cylichna Gouldii*. The *Diaphana pertenuis* (Migh.) is very distinct from it.

Loripes lens Verrill and Smith, sp. nov.

Shell white, well-rounded, nearly equilateral, slightly convex, thin; lunule small, cordate, deeply excavated; sculpture slightly raised, concentric lines of growth, distinct at the ends, but nearly obsolete on the median portion of the shell. Posteriorly the outline is more obtusely rounded, so as to form a rounded angle with the dorsal and ventral edges; dorsal edge incurved in front of the beaks; a faint undulation runs from the beak to the posterior angle. Teeth none. Length, 14; height, 12·5^{mm}. Stations 865 to 872; 873 to 879, common. Also dredged off Cape Cod, 1879, in many places (40 to 120 fathoms).

Modiola polita Verrill and Smith, sp. nov.

Shell thin, translucent, without sculpture; epidermis pale yellow, smooth and polished. Umbos prominent; hinge-line straight; posterior end broadly rounded, compressed; anterior end prolonged decidedly beyond the beak, narrow, rounded. Greatest length, 40; breadth, 21^{mm}. Station 895, two specimens.

Pecten fenestratus Forbes (?).

The small species that I refer doubtfully to this species is beautifully marbled with brown, red and white. The ears are prominent. The lower valve is covered with thin concentric riblets, while the upper valve is cancellated with fine radiating and concentric raised lines. Station 872.

Echinoderms.

The star-fishes and ophiurans were exceedingly abundant and beautiful at all the stations, and many species not known previously on our coast were taken, several of which appear to be undescribed, while others were known only from northern Europe, or from the deep waters off Florida. Many of the species have only recently been obtained from the northern fishing banks off Nova Scotia, and are recorded in this Journal. One new species of *Archaster* (*A. Americanus*) was particularly abundant, several thousands of specimens having been taken; but the two largest and most beautiful species of this genus were *Archaster Agassizii* (new) and *A. Floræ*. Of *Odontaster hispidus*, over 100 were taken. One of the most conspicuous star-fishes was the remarkable *Pteraster multipes* Sars,* one specimen of which was over six inches in diameter, and very thick and heavy. Its color, in life, is rich purple above, with the lower side orange, streaked with brown, and

* This species differs so widely from typical *Pteraster* as to merit generic separation. I propose for it the name *Diplopteraster*, characterized especially by having suckers in four rows, and by having the horizontal radiating interbrachial spines of the lower surface imbedded in, and concealed by, a thick skin, when adult, (exposed in the young).

with large dark purple suckers. A large and handsome orange-colored species of *Luidia* (apparently *L. elegans*) often ten to fifteen inches broad, was very common, but nearly all the specimens dismembered themselves before they came to the surface. Large specimens of two Floridian sea-urchins (*Echinus gracilis* and *E. Norvegicus*) were taken.

Partial List of Echinodermata.

E. = European; F. = off Florida; *n.* = northern coasts of New England or Nova Scotia; * = new species. Numbers refer to list of stations; ab. = abundant.

n. *Thyone scabra* Verrill. (876, 877.)
Caudina. (876.)
n. *Schizaster fragilis* D. & Kor. (865, 871, 873, 874, 876, ab., 877, ab.)
F. *Echinus gracilis* A. Ag. (872, two large specimens.)
F. *Echinus Norvegicus* D. & K.
F. *Temnechinus maculatus* A. Ag.
Asterias vulgaris Stimp. (869, one sp.)
* *Asterias Tanneri* V., nov. (869, 870, 871, 872, 877.)
n. *Stephanasterias albula* (Stimp.) Verrill. (865, 866, ab., 871, 872.)
Cribrella sanguinolenta Lütk. (871, 872.)
E. *Diplopteraster multipes* (Sars) Verrill. (869, one very large, 880, two, 895, one.)
n. *Porania grandis* Verrill. (869, several, 872.)
n. *Porania spinulosa* Verrill. (869, 879, three, 894, 895.)
n. *Porania borealis* Verrill (= *Asterina borealis* V.) (869, several, 879, few.)
* *Odontaster hispidus* V., gen. nov. (865, 869, ab., 871, 872, ab., 873, 878, 894, 895.)
n. *Archaster Floræ* Verrill. (869, several, large, 879, 881, 895.)
* *Archaster Americanus* V. (865–8, very ab., 871, ab., 873, 877, ab., 879.)
* *Archaster Agassizii* V. (879, 880, sev., 881, sev., 891–894.)
n. *Archaster Parellii* D. & K. (879, 892–894.)
F. *Luidia elegans* Perrier. (865–872, many large, 873, 876, 877.)
n. *Ctenodiscus crispatus* D. & Kor. (879, one.)
Ophiopholis aculeata Gray. (865, 869, 872, 879, 895.)
n. *Ophioglypha Sarsii* Lyman. (865–869, ab., 870, ab., 871, 877, ab., 879, 895.)
n. *Ophioglypha affinis* Lyman. (869, 875, 877, 878.)
* *Ophioglypha.* (879, 880, 895.)
n. *Ophiacantha millespina* Verrill. (869, ab., 871.)
n. *Ophioscolex glacialis* M. & Tr. (869, 871.)
n. *Amphiura Otteri* (?) Ljung.
Amphiura. (865, 879.)
Amphiura. (880, two.)
F. *Ophiocnida olivacea* Lym. (869, 871, ab., 872, 873–877, ab.)
n. *Antedon Sarsii* (D. & K.) (870, 871, 873–876, 878–880.)

Asterias Tanneri Verrill, sp. nov.

A large, handsome, five-armed, dark red species, with a small disk and long narrow arms. Radii about as 1 : 7. Skeleton-plates rather strong. Lateral and dorsal spines one to a plate, elongated, round, tapering, forming five simple rows, in adults; in young, only three distinct rows. Ventral spines, long, obtuse, two to a plate, forming a double row, remote from the lateral, with large groups of papillæ between. Adambulacral spines long, slender, two to a plate, divergent, forming two regular rows. Minor pedicellariæ form close wreaths around bases of lateral and dorsal spines, and clusters on outer side of external ventrals; major ones, large, long-ovate, pointed,

scattered between the dorsal spines and clustered around their bases. Radius of disk, 11; of arms, 75^{mm}; larger specimens, 250^{mm} in diameter, were secured, but most of them had dismembered themselves, before reaching the surface.

Odontaster Verrill, gen. nov.

Form and appearance like *Archaster;* two rows of marginal plates; dorsal surface with paxillæ; ventral plates polygonal, spinulose. Each jaw bears a large, strong, sharp, erect or everted tooth, outside of the marginal spinules.

Odontaster hispidus V., sp. nov.

Rays five, rarely six, broad, tapering, sub-acute; body broad, densely spinulose beneath, flattened dorsally; larger paxillæ, each with a group of fifteen to twenty slender, equal, divergent spinules; those near the marginal plates much smaller. Upper marginal plates squarish, densely covered with small, sharp spinules; lower ones with larger and longer spinules; ventral plates, each with a crowded group of six or eight larger, stout, acute spinules, varying in stoutness; adambulacral plates, each with two, three, or more, blunt spinules, on the inner edge, in a row, and others, of similar form, outside of them. Central tooth of jaws with sharp, smooth tip, straight or recurved, longer and much larger than adjacent spines. Color pale salmon, or yellowish, when living. Radius of disk, 15; of arms, 42^{mm}.

Archaster Americanus Verrill, sp. nov.

Arms five, rarely six, long, regularly tapered, moderately broad, rather flat. Radius of disk to that of arms, commonly, 1 : 5. Color in life, pale yellow, orange-yellow, or salmon. Dorsal area covered with slender paxillæ, not crowded, each bearing a stellate group of eight to ten very slender, long spinules, with a central one of the same size. Upper marginal plates rather large, elongated vertically, densely covered with small spinules, which radiate around the margin; sometimes a few plates, in the angles between the arms, bear, each, a single spine, at the upper end. Lower plates large, broad, reaching nearly to the ambulacral groove, covered with slender, sharp spinules, the middle row longest; two or three of the outermost of these are much longer and larger than the rest, and more or less flattened. Ventral plates very few, spinulose. Adambulacral plates, each with an inner group of three or four slender spines, in a row, and an irregular outer group of three or four larger ones; jaw-spines numerous, blunt. Largest specimens have the larger radius 74; lesser 12^{mm}.

Archaster Agassizii Verrill, sp. nov.

A large and elegantly formed species, with rather large pentagonal disk and wide, rapidly tapered arms. Color, in life, bright orange-red.

Dorsal surface closely covered with large, even paxillæ, which are crowned with very numerous, short, blunt, granule-like spinules, six or eight larger ones forming a central group, with twenty to thirty smaller and more acute ones fringing the border; next the marginal plates the paxillæ are smaller and crowded; a group of larger and more conspicuous ones surrounds and partially covers the large madreporic plate. Upper and lower marginal plates equal in number and nearly so in size, their sutures coincident; proximal plates higher than long; those toward the ends of the arms nearly square; all are densely covered with small rounded granules; in many specimens the lower marginal plates bear, each, a single short, stout, blunt spine, on the outer side, but these are often partially wanting, and sometimes entirely absent. Ventral plates form triangular areas, extending out a short distance on the arms; they are angular, covered with short, rounded spinules, and form a close pavement. Adambulacral plates bear, each, about seven or eight slender, nearly equal spines, in one row, with a group of outer, small, short spinules. Greater radius 57; lesser 21^{mm}.

Luidia elegans? Perrier. Arch. Zool. Expér., p. 256, 1876.

The species taken by us grows to more than 350^{mm} in diameter. Color deep orange above, lighter below. Paxillæ crowded, smallest in middle of arms; large laterally; each bears a large group of slender spinules, and usually one to three larger, blunt pedicellariæ. Marginal plates with a vertical row of three long, tapering, acute spines, the upper ones largest; adambulacral plates also with a row of three sharp spines, which are smaller and recurved; the middle one largest. A row of large, ovate, bilabiate pedicellariæ between the lateral and adambulacral plates. The specimen described by Perrier was very young, if of this species.

ART. XLII.—*Revision of the Land Snails of the Paleozoic era, with Descriptions of New Species;* by J. W. DAWSON.

THE Gasteropods as a class occur as early as the Upper Cambrian, but all the earlier known types are marine. That portion of the group distinguished by the possession of air sacs instead of gills (Pulmonifera) has not hitherto been found in any formation older than the Carboniferous, and only four Carboniferous species have been described. In the present paper

I propose to state some additional facts respecting the species already known, to discuss their affinities, and to describe two additional species, making six in all from the Paleozoic rocks, including one from the Erian or Devonian. For reasons to be mentioned in the sequel, I do not admit the genus *Palæorbis* founded, by some German naturalists, on fossils which I believe to be tubes of Annelids.

It may be useful to premise that of the two leading subdivisions of the group of Pulmonifera, the Operculate and Inoperculate, the first has been traced no farther back than the Eocene. The second, or Inoperculate division, includes some genera that are aquatic and some that are terrestrial. Of the aquatic genera no representatives are known in formations older than the Wealden and Purbeck, and these only in Europe. The terrestrial group or the family of the *Helicidæ*, which, singularly enough, is that which diverges farthest from the ordinary gill-bearing Gasteropods, is the one which has been traced farthest back, and includes the Paleozoic species. It is further remarkable that a very great gap exists in the geological history of this family. No species are known between the Carboniferous and the early Tertiary, though in the intervening formations there are many fresh-water and estuarine deposits in which such remains might be expected to occur. There is perhaps no reason to doubt the continuance of the Helicidæ through this long portion of geological time, though it is probable that during the interval the family did not increase much in the number of its species, more especially as it seems certain that it has its culmination in the modern period, when it is represented by very many and large species, which are dispersed over nearly all parts of our continents.

The mode of occurrence of the Paleozoic Pulmonifera in the few localities where they have been found is characteristic. The earliest known species, *Pupa vetusta*, was found by Sir Charles Lyell and the writer, in the material filling the once hollow stem of a Sigillaria at the South Joggins in Nova Scotia, and many additional specimens have subsequently been obtained from similar repositories in the same locality, where they are associated with bones of Batrachians and remains of Millipedes. Other specimens, and also the species *Zonites priscus*, have been found in a thin, shaly layer, containing debris of plants and crusts of Cyprids, and which was probably deposited at the outlet of a small stream flowing through the coal-formation forest. The two species found in Illinois occur, according to Bradley, in an underclay or fossil soil which may have been the bed of a pond or estuary, and subsequently became a forest sub-soil. The Erian species occurs in shales charged with remains of land plants, and which must consequently have

received abundant drainage from neighboring land. It is only in such deposits that remains of true land-snails can be expected to occur; though, had fresh-water or brackish water Pulmonates abounded in the Carboniferous age, their remains should have occurred in those bituminous and calcareo-bituminous shales which contain such vast quantities of debris of Cyprids, Lamellibranchs and fishes of the period, mixed with fossil plants.

With reference to their affinities, the Paleozoic land snails present no very remarkable peculiarity except their close resemblance to some modern forms. Of the known species, four belong to the genus *Pupa* in its wider sense, and are very near to sub-generic types still represented on the American continent and its islands. One is a small helicoid shell not separable from the modern genus *Zonites*, and the remaining one, though it has been placed in a new genus, is very near to some small American snails of the present day (*Stenotrema*, etc.) All the species are of small size, though not smaller than some modern shells of the same types.

I shall now proceed to give the characters and descriptions of the several species, adding to the account of those previously known, such new facts as have occurred in my more recent explorations and examinations. I should state here that many of the new facts detailed have been obtained in the course of excavations for the extraction of erect trees holding land animals, undertaken with the aid of a grant from the Government fund for aiding original researches, at the disposal of the Royal Society of London, and carried on within the past three years.

1. *Pupa vetusta* Dawson. (Figs. 1 to 4, and 14, *a*, *b*.)

[Sir C. Lyell and Dr. Dawson on Remains of Reptiles and a Land shell from the South Joggins in Nova Scotia, Journal of Geological Society of London, vol. ix, 1832 (figured but not named). Dawson's Acadian Geology, 1855, p. 160. Dawson's Air-breathers of the Coal Period, 1863. Acadian Geology, 2d and 3d editions, p. 384, 1868 and 1879.]

Description.—Shell cylindrical, somewhat abruptly conical at the apex, in some specimens tending to diminish in diameter in the later turns or whorls of the shell. Whorls nine in adult shells, slighly convex, in width equal to half the diameter of the shell. Suture impressed. Aperture evenly rounded, not continuous above, rather longer than broad, destitute of teeth; peristome slightly reflected and smooth. Surface shining, marked with longitudinal smooth ridges, separated by spaces a little wider than the ridges; spaces about $\frac{1}{60}$th inch in width. Shell calcareous, thin, prismatic in structure. Young specimens abruptly conical and helicoid in form. Nucleus round, smooth, the first turn below the nucleus marked with

rows of little pits which gradually pass into the continuous striæ. The last whorl of the adult presents irregular lines of growth, instead of the regular microscopic ribs of the middle turns. Mature ovum membranous, or so slightly calcareous that it can be compressed without breaking: the embryo shell sometimes visible within. Length of adult shell rather less than 1 centimeter, breadth in middle 4 millimeters.

Variety tenuistriata.—Along with the ordinary form there are others of similar size and general structure, but with the apex less obtuse and a somewhat greater tendency to diminish in diameter in the later whorls. They have also the microscopic ridges in the shell about half as far apart as those of the ordinary form. This form I was at first disposed to regard as specifically distinct, but there seems to be a gradual transition from one to the other, and the two forms seem to accompany each other throughout the entire range of the species.

State of preservation.—The shells are usually entire, but often somewhat flattened, and cracked or distorted in the process. Many fragments of shells, however, occur with the entire specimens, and some of these have a whitened or bleached appearance like that of modern land shells after having been exposed to the weather. In one layer I found impressions of several flattened shells, the substance of the shell having been altogether removed. Ordinarily the shell remains in such a state as to show its structure, and the more perfect specimens found in the erect trees have a grayish brown color, like that of some modern Pupæ.

The habitat of this species was in forests of the Coal-formation period, composed of *Sigillaria*, *Calamites*, *Lepidophloios* and *Ferns*. The only known locality is the South Joggins, Nova Scotia. At this place the shells have been obtained in considerable numbers, though perfect specimens which can be disengaged from the matrix, are comparatively few. They have been found in erect *Sigillariæ* and also in a bed of shale. The lowest and highest beds in which they occur are separated by 2,000 feet of vertical thickness of strata including no less than thirty-five beds of coal and many underclays supporting erect trees, so that the species must have inhabited this locality for a very long time and must have survived many physical vicissitudes.

The first specimen, which was also the first known Paleozoic land shell, was found by Sir Charles Lyell and the writer in 1851, in breaking up the contents of an erect tree holding reptilian bones. The specimens obtained from this tree having been taken by Sir Charles to Cambridge and submitted to the late Prof. Jeffries Wyman, the shell in question was recognized by him and the late Dr. Gould, of Boston, as a land shell. It

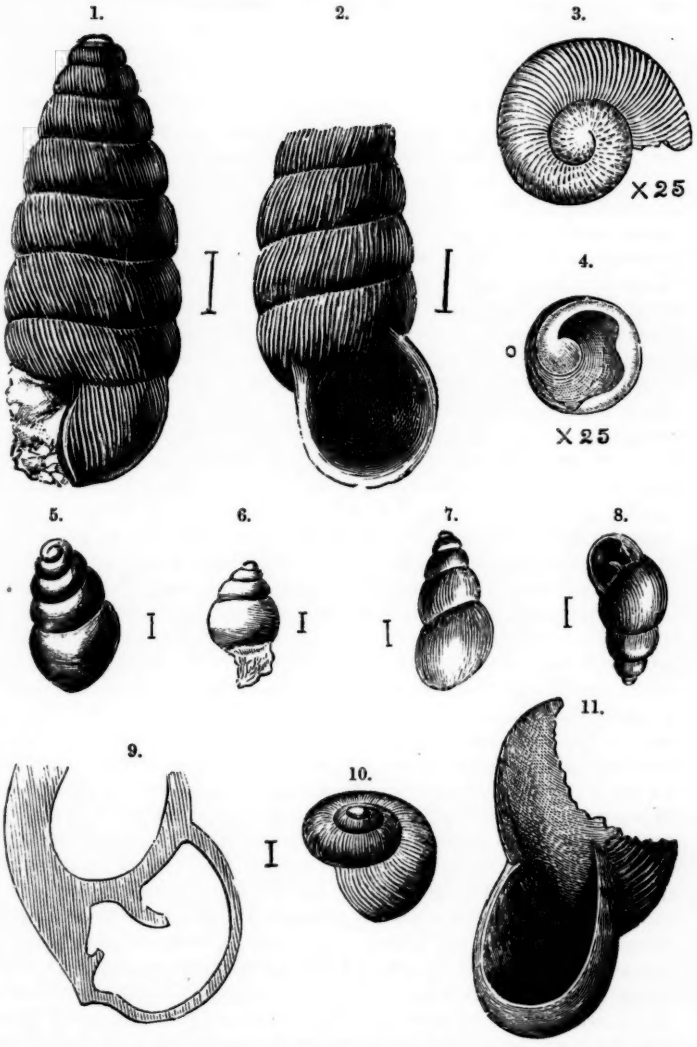


Fig. 1, *Pupa vetusta*, magnified 8 times lineally; 2, same, showing the aperture, ×8; 3, same, nuclear whorl, ×25; 4, same, mature egg and embryo shell, ×25. 5, 6, *Pupa Bigsbii*, ×8. 7, *Pupa Vermilionensis*, ×8; 8, same, showing aperture ×8, the small tooth on the columella somewhat exaggerated; 9, same, section of aperture, showing tooth ×16. 10, *Zonites priscus*, ×8; 11, same, crushed specimen, showing aperture ×20.

was subsequently examined by M. Deshayes and Mr. Gwyn Jeffries, who concurred in this determination; and its microscopic structure was described by the late Prof. Quekett, of London, as similar to that of modern land shells. The single specimen obtained on this occasion was somewhat crushed and did not show the aperture. Hence the hesitation as to its nature, and the delay in naming it, though it was figured and described in the paper above cited in 1852. Better specimens showing the aperture were afterward obtained by the writer, and it was named and described by him in his "Air-breathers of the Coal Period," in 1863. Prof. Owen, in his 'Palæontology,' subsequently proposed the generic name *Dendropupa*. This I have hesitated to accept, as expressing a generic distinction not warranted by the facts; but should the shell be considered to require a generic or sub-generic distinction, Owen's name should be adopted for it. There seems, however, nothing to prevent it from being placed in one of the modern sub-genera of simple-lipped Pupæ. With regard to the form of its aperture, I may explain that some currency has been given to an incorrect representation of it, through an unfortunate accident. In the case of delicate shells like this, imbedded in a hard matrix, it is of course difficult to work out the aperture perfectly; and in my published figure in the "Air-breathers," I had to restore somewhat the broken specimens in my possession. This restoration, specimens subsequently found have shown to be very exact. Nevertheless it was criticised by some English conchologists, and when Sir Charles Lyell was about to publish his Student's Manual, he asked me to give him one of my best specimens to be figured. This I sent with micro-photographs of others. It seems, however, that the artist or engraver mistook the form of the aperture and gave it an entirely unnatural appearance in the Student's Manual. That now given is taken from a photograph of the most perfect and least compressd specimen in my possession.

As already stated, this shell seems closely allied to some modern Pupæ. Perhaps the modern species which approaches most nearly to it in form, markings and size, is *Macrocheilus Gossei* from the West Indies, specimens of which were sent to me some years ago by Mr. Bland, of New York, with the remark that they must be very near to my Carboniferous species. Such edentulous species as *Pupa* (*Leucochila*) *fallax* of Eastern America very closely resemble it; and it was regarded by the late Dr. Carpenter as probably a near ally of those species which are placed by some European conchologists in the genus *Pupilla*.

The lowest bed in which *Pupa vetusta* occurs belongs to group VIII of Division 4 of my section of the South Joggins,

and is between Coal 37 and Coal 38 of Logan's section, being about 42 feet below Coal 37. The next horizon, and that in which the shell was first discovered, is 1217 feet of vertical thickness higher, in group XV of Division 4 of my section. The shells occur here in erect *Sigillariæ*, standing on Coal 15 of Logan's section. The third horizon is in group XXVI of Division 4, about 800 feet higher than the last. Here also the shells occurred in an erect *Sigillaria.*

In the lowest of these three horizons, the shells are found, as already stated, in a thin bed of concretionary clay of dark gray color, though associated with reddish beds. It contains *Zonites priscus* as well, though this is very rare, and there are a few valves of *Cythere* and shells of *Naiadites* as well as carbonaceous fragments, fronds of ferns, *Trigonocarpa*, etc. The *Pupæ* are mostly adult, but many very young shells also occur, as well as fragments of broken shells. The bed is evidently a layer of mud deposited in a pond or creek, or at the mouth of a small stream. In modern swamps, multitudes of fresh-water shells occur in such places, and it is remarkable that in this case the only gasteropods are land shells, and these very plentiful, though only in one bed about an inch in thickness. This would seem to imply an absence of fresh-water Pulmonifera. In the erect *Sigillariæ* of group XV, the shells occur either in a sandy matrix, more or less darkened with vegetable matter, or in a carbonaceous mass composed mainly of vegetable debris. Except when crushed or flattened, the shells in these repositories are usually filled with brownish calcite. From this I infer that most of them were alive when imbedded, or at least that they contained the bodies of the animals; and it is not improbable that they sheltered themselves in the hollow trees, as is the habit of many similar animals in modern forests. Their residence in these trees as well as the characters of their embryology are illustrated by the occurrence of their mature ova. They may also have formed part of the food of the reptilian animals whose remains occur with them. In illustration of this I have elsewhere stated that I have found as many as eleven unbroken shells of *Physa heterostropha* in the stomach of a modern *Menobranchus.* I think it certain, however, that both the shells and the reptiles occurring in these trees must have been strictly terrestrial in their habits, as they could not have found admission to the erect trees unless the ground had been sufficiently dry to allow several feet of the imbedded hollow trunks to be free from water. In the highest of the three horizons the shells occurred in an erect tree, but without any other fossils, and they had apparently been washed in along with a grayish mud.*

* The discovery of the shells in this tree was made by Albert I. Hill, C.E.

2. *Pupa Bigsbii* s. n. (Figs. 5 and 6.)

Description.—Shell half the size of *Pupa vetusta*, or between three and four millimeters in length and one and five-tenths millimeters in breadth. Form, long conical. Body whorl about one-third of the entire length, giving the shell a somewhat bulimoid form. Whorls five in the largest specimens found, tumid, suture much impressed. Surface smooth. Aperture apparently oval in form, but not perfectly known, as the body whorl is crushed in all the specimens.

A few specimens, none of them quite perfect, were found in the erect trees of group XV at the Joggins, along with *Pupa vetusta*. They differ from that species in smaller size, different form and absence of sculpture. The specimens do not show whether the aperture was toothed or simple, but it was probably the latter, as the lip is evidently very thin and delicate. From its form it is probable that it belongs to a different subgenus from *P. vetusta*. It is very much more rare than that species in the erect trees, and has not been found elsewhere.

I dedicate it to my venerable and dear friend Dr. Bigsby, F.R.S., of London, a pioneer in American geology, and still an indefatigable worker in the science.

3. *Pupa Vermilionensis* Bradley. (Figs. 8 and 9, and 14*c*.)

[Bradley in Report of Geological Survey of Illinois, vol. iv, p. 254. Id. in Am. Journ. Sci., III, vol. iv, p. 87.]

*Description.**—Shell spindle-shaped, tapering to an obtuse apex, covered with microscopic ridges (25 to 30 in a millimeter) parallel to the lines of growth. Aperture oblique, oval. Outer lip thin, slightly reflexed. Columella lip reflexed, thickened; furnished with a single central curved tooth, projecting nearly half way across the aperture. Junction of columella and outer lip somewhat angular and dentiform. In old individuals the columella tooth is often continuous through an entire turn or farther. It is not seen on shells having less than three turns. The last turn forms nearly half the length of the shell. Whorls rounded. Suture impressed. Surface glossy. Color black or gray. Length three and six-tenths millimeters. Width two millimeters. Some individuals are smooth or destitute of the fine microscopic ridges, but whether this is a natural peculiarity or a result of injury to the outer surface, is not certain.

As compared with *Pupa vetusta* this shell is less than half the size, of a less cylindrical form, its whorls more rounded, and its body whorl much larger in proportion. Its sculpture is much finer. The conspicuous tooth in the aperture is of

* Slightly modified from Bradley.

course also a strong mark of distinction. The shell is thin, and from its black color and failure to show structure under the microscope, I infer that it must have been of a horny or corneous texture, with little calcareous matter. The matrix is light colored and concretionary, and somewhat hard and calcareous.

As compared with modern American species, *P. Vermilionensis* is very near to several of the smaller forms with teeth in the aperture. In its form and aperture it approaches closely to *P.* (*Leucochila*) *corticaria* of Say, or to the immature shell of *P. rupicola*. It has also some resemblance to the western species *P. hordeacea* Gabb, from Arizona.

This shell was discovered by the late Mr. F. H. Bradley in 1869, in concretionary limestone accompanying the underclay of Coal No. 6, Wabash Valley Section, at Pelly's Fort, Vermilion River, Illinois. In the first notice, which appeared in the Report of the Geological Survey of Illinois, it was referred to *Pupa vetusta*, but was subsequently described by Mr. Bradley in the American Journal of Science, under the name above cited.

I am indebted for specimens of this shell to Mr. John Collett, of the Geological Survey of Indiana, and also to Mr. W. Gurley, of Danville, Illinois.

4. *Zonites* (*Conulus*) *priscus* Carpenter. (Figs. 10 and 11, and 14*d*.)

[Quarterly Journal of Geological Society of London, Nov. 1867. Acadian Geology, 2d edition, 1868, p. 385.]

*Description.**—Shell small, helicoid. Length two and five-tenths millimeters, width two and eight-tenths millimeters. Spire little elevated. Nucleus small. Whorls four, somewhat flattened, with the suture little impressed. Base somewhat excavated with large umbilicus. Aperture oblique, suboval, somewhat regularly rounded. Lip simple. Surface marked with uneven striæ and somewhat more conspicuous ridges of growth. Angle of divergence about 130°. Shell thin and probably horny.

This little shell was discovered in 1866, in the bed already referred to as the lowest of those at the South Joggins in which *Pupa vetusta* has been found. Shortly after I had discovered this bed, being impressed with the probability that it might hold other remains of land animals beside the *Pupa*, I had some excavations made in it, and a considerable quantity of material taken out. I found, however, that the thin layer containing the land shells was not continuous but in limited patches, and was rewarded only by the discovery of a few

* Slightly modified from Carpenter.

specimens of *Zonites priscus* and a small and not determinable fragment of bone, in addition to specimens of *Pupa vetusta*.

The specimens found at this time were submitted to the late Dr. P. P. Carpenter, by whom the species was named and described. One or two crushed specimens have been subsequently found in the erect trees holding *Pupa vetusta* in group XV, but the species is extremely rare in comparison. This may however have depended on some difference in habitat or mode of life, rendering it less likely to be imbedded in the deposits in process of formation. It is also to be observed that the shell is much more delicate than that of *Pupa vetusta*, and therefore less likely to be preserved.

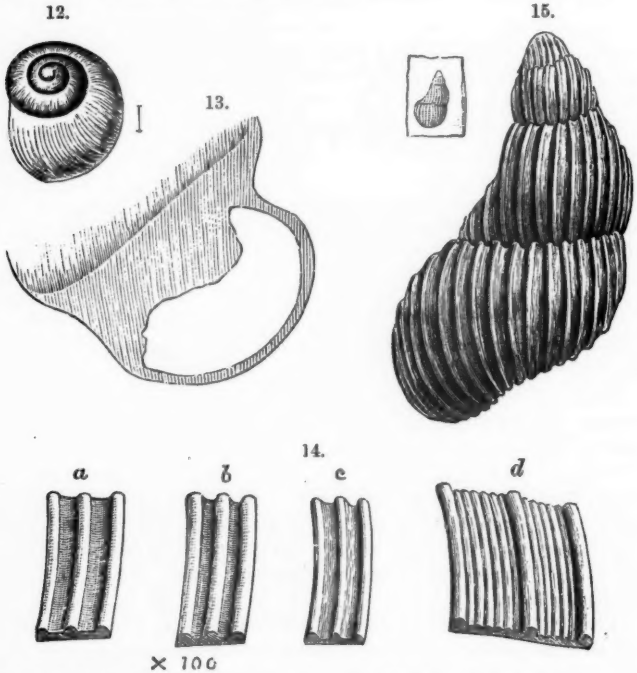


Fig. 12, *Dawsonella Meeki*, ×8; 13, same, section of aperture, ×16; the outer edge of the lamella is imperfect. 14, Markings of surface ×100: (*a*) *Pupa vetusta*; (*b*) *Pupa vetusta* var. *tenuistriata*; (*c*) *Pupa Vermilionensis*; (*d*) *Zonites priscus*; 15, *Strophites grandæva*, natural size and magnified 8 diameters.

With regard to its affinities, it was compared by Dr. Carpenter with the African species *Paryphanta Caffra* Fer., "on an extremely small scale." Dr. Carpenter also compared it with *Hygromia*, and stated that it might well be ranked under *Pseu-*

dohyalina of Morse, with the living species *minuscula* and *exigua*. He thought it best, however, to place it in the subgenus *Conulus* of the genus *Zonites*, as defined by Messrs. Adams. With regard to the subgeneric name, Dr. Carpenter explained that the subgenus *Conulus* of Fitz, 1833, appears to be synonymous with *Trochiscus* Held, 1837 (non Sby.); also with *Petasia* Beck, 1837; and with *Perforatella* Schlütt.; and according to Adams is a subgenus of *Zonites* Montf. (non Leach, Gray). Those who do not care to enter into these subgeneric distinctions, may designate the species as a *Zonites*, or even, speaking loosely, as a *Helix*. There seems nothing in its characters to separate it, more than specifically, from many of our smaller helicoid snails with thin shells and simple aperture.

5. *Dawsonella Meeki* Bradley. (Figs. 12 and 13.)

[Report of Geological Survey of Illinois, vol. iv, p. 254. Am. Journ. of Sci., III, vol. iv, p. 88. Ibid, vol. vii, p. 157.]

*Description.**—Shell broad, depressed, helicoid. Spire obtuse, consisting of three to three and one-half turns. Length three and two-tenths millimeters, width four millimeters. Surface smooth, but with fine microscopic lines of growth, about fifteen in a millimeter. Aperture oblique, oval, greatly contracted by a broad lamellar expansion of the columella, extending more than half way across, even in small individuals. Outer lip thickened, slightly reflexed. Suture little impressed, imperforate, but last turn slightly excavated in the umbilical region. The shell is usually black in color, and under the microscope shows no distinct structure, from which it may be inferred that it was corneous in texture. It is thicker than the shell of *Zonites priscus*.

This species is found along with *Pupa Vermilionensis*, and was discovered by Bradley, who was, however, at first disposed to refer it to genus *Anomphalus* of Meek; but subsequently, and with good reason, regarded it as distinct and as a land shell. In size and general form it resembles *Zonites priscus*, though expanding less rapidly and with rounder whorls; but it is at once distinguished by its want of the somewhat coarse sculpture of that species, and by the plate which partially covers its aperture. Its nearest modern allies in eastern America would seem to be such shells as *Helix* (*Triodopsis*) *palliata*, and *H.* (*Stenotrema*) *monodon*.

For specimens of this shell I am indebted to the persons above named as having furnished specimens of *Pupa Vermilionensis*.

6. *Strophites grandæva*, s. n. (Fig. 15.)

Description.—Shell cylindrical, with obtuse apex. Whorls four or more. Surface covered with sharp vertical ridges,

* Modified from Bradley.

separated by spaces three times as wide. The body whorl about 4 millimeters in diameter, with about thirteen vertical ridges visible on one side. Length of a specimen probably not quite perfect, about 8 millimeters. The shell, which has disappeared, must have been very thin, and the surface remaining is smooth and shining. In general form, so far as can be ascertained from a very imperfect specimen, this shell must have closely resembled the modern Pupæ of the genus *Strophia* of Albers.

The only specimen known is from the Erian (Devonian) plant-beds of St. John, New Brunswick, which, besides affording great numbers of remains of land plants, have produced the only Erian insects as yet known. It was sent to me by Mr. G. F. Matthew, of St. John, along with specimens of fossil plants, several years ago, but I hesitated to describe it, waiting in hope of additional specimens. As these have not occurred, and I have now carefully examined the whole of the material from these beds to which I have been able to obtain access, I venture to name it as probably the oldest known land shell, the beds in which it is found being either middle or upper Erian.

If a land snail, it is larger in size and probably of higher type than any of those known from the Coal-formation. This would not be wonderful, when we consider the greater variety of surface and the high character of the vegetation, which, as I have elsewhere endeavored to show, distinguished the later Erian age in Northeastern America.

Concluding Remarks.

It may be proper to mention here the alleged Pulmonifera of the genus *Pulæorbis* described by some German naturalists. These I believe to be worm-tubes of the genus *Spirorbis*, and in fact to be nothing else than the common *S. carbonarius* or *S. pusillus* of the Coal-formation. The history of this error may be stated thus. The eminent paleobotanists Germar, Gœppert and Geinitz have referred the *Spirorbis*, so common in the Coal-measures to the fungi, under the name *Gyromyces*, and in this they have been followed by other naturalists, though as long ago as 1868 I had shown that this little organism is not only a calcareous shell, attached by one side to vegetable matters and shells of mollusks, but that it has the microscopic structure characteristic of modern shells of this type.* More recently Van Beneden, Cœnius and Goldenberg, perceiving that the fossil is really a calcareous shell, but apparently unaware of the observations made in this country by myself and Mr. Lesquereux, have held the *Spirorbis* to be a pulmonate mollusk allied to *Planorbis*, and have supposed that its presence on fossil

* Acadian Geology, 2d edition, p. 205.

plants is confirmatory of this view, though the shells are attached by a flattened side to these plants, and are also found attached to shells of bivalves of the genus *Naiadites*. Mr. R. Etheridge, Jr., of the Geological Survey of Great Britain, has recently summed up the evidence as to the true nature of these shells, and has revised and added to the species, in a series of articles in the Geological Magazine of London, vol. viii.

If we exclude the alleged *Palæorbis* above referred to, all the Paleozoic Pulmonifera hitherto found are American. Since, however, in the Carboniferous age, Batrachians, Arachnidans, Insects and Millipedes occur on both continents, it is not unlikely that ere long European species of land snails will be announced. The species hitherto found in Eastern America, are in every way strangely isolated. In the plant-beds of St. John, about 9,000 feet in thickness, and in the Coal-formation of the South Joggins, more than 7,000 feet in thickness, no other Gasteropods occur, nor, I believe, do any occur in the beds holding land snails in Illinois. Nor, as already stated, are any of the aquatic Pulmonifera known in the Paleozoic. Thus, in so far as at present known, these Paleozoic snails are separated not only from any predecessors, if there were any, or successors, but from any contemporary animals allied to them.

It is probable that the land snails of the Erian and Carboniferous were neither numerous nor important members of the faunæ of those periods. Had other species existed in any considerable numbers, there is no reason why they should not have been found in the erect trees, or in those shales which contain land plants. More especially would the discovery of any larger species, had they existed, been likely to have occurred. Further, what we know of the vegetation of the Paleozoic Period would lead us to infer that it did not abound in those succulent and nutritious leaves and fruits which are most congenial to land snails. It is to be observed, however, that we know little as yet of the upland life of the Erian or Carboniferous. The animal life of the drier parts of the low country is indeed as yet very little known; and but for the revelations in this respect of the erect trees in one bed in the Coal-formation of Nova Scotia, our knowledge of the land snails and Millipedes, and also of an eminently terrestrial group of reptiles, the *Microsauria*, would have been much more imperfect than it is. We may hope for still further revelations of this kind, and in the meantime, it would be premature to speculate as to the affinities of our little group of land snails with animals either their contemporaries or belonging to earlier or later formations, except to note the fact of the little change of form or structure in this type of life in that vast interval of time which separates the Erian Period from the present day.

ART. XLIII.—*Extension of the Carboniferous Formation in Massachusetts;** by W. O. CROSBY and G. H. BARTON. (Contributions from the Geological Department of the Massachusetts Institute of Technology: No. I.)

THE Carboniferous strata of Massachusetts and Rhode Island are all found within the limits of what is known as the Narragansett basin; the well-marked geological basin holding Boston and its environs being, in our opinion, entirely filled with rocks of Primordial age. The northern and western boundaries of the Narragansett basin have about the latitude and longitude, respectively, of the northeast corner of Rhode Island, tending to form a right angle at this point. But the angle is not closed, for the basin gives off a long, narrow branch or arm here which sweeps first in a northeasterly and then in an easterly direction to Braintree in Massachusetts, where, at a distance of more than twenty-five miles from its origin, it nearly, but probably not quite, connects with the Boston basin. The nearest outcrops in the two basins are about two miles apart, are entirely dissimilar lithologically, and are certainly widely separated in time. The intervening ground is a thick deposit of drift, and, although its contours are not unfavorable to the theory that the basins communicate, yet it is probably underlaid by granite, which is the predominant underlying rock of all this region. This elongated arm of the Narragansett basin lies wholly within the limits of Norfolk County; and, hence, it has received the local designation of the Norfolk County basin. Its breadth varies from a small fraction of a mile to two and one-third miles; and it is widest in the middle part, being very much contracted toward each end.

President Hitchcock long ago established the Carboniferous age of the coal-bearing strata of the Narragansett basin. These are well developed on the island of Aquidneck, and also form a broad, semi-circular belt reaching from Warwick and Providence northerly by Valley Falls to Wrentham in Massachusetts, and thence easterly through Attleboro and Mansfield into Bridgewater.

South and east of this band of undisputed coal-measures is

* This communication is an abstract embodying the more important results of an extended paper, illustrated with maps and sections, on the "Geology of the Norfolk County basin in Massachusetts." The original essay represents nearly four months of field and laboratory work, performed chiefly by Mr. Barton, and formed his thesis for graduation in the Class of 1880 of the Massachusetts Institute of Technology. We wish to acknowledge our great obligations to Professor W. H. Niles for material assistance rendered in many ways, and also to Hon. John Cummings and President W. T. Hart of the New York and New England Railroad for free transportation while engaged upon the field-work.

a wide area of conglomerate, extending to the limits of the basin. This great development of conglomerate was regarded by Hitchcock as underlying the coal strata, and as probably of Silurian age. While the stratified rocks lying to the northwest of the anthracite belt, and composing the attenuated Norfolk County basin, were finally referred provisionally by this distinguished geologist, and mainly upon lithological grounds, to the Devonian system, and Sir Charles Lyell, in a paper on the Worcester Anthracite,* appears to concur in this conclusion.

Of the former, if not the present, existence of Cambrian (Lower Silurian) strata in the Narragansett basin there can be but little doubt, since pebbles holding Primordial fossils—Scolithus and Lingula—are of common occurrence in the conglomerate at Newport, Fall River and Taunton; and yet this great conglomerate itself is now generally and, as we think, justly regarded as essentially a part of the Carboniferous series. That all previous determinations of the age of the Norfolk County beds have rested on insufficient evidence is obvious; and to improve this state of things was one of the principal objects of our investigation. A variety of opinions has been held concerning the horizon of this belt, it having been referred by different observers to the Primordial, Devonian, Carboniferous and Triassic systems. Almost the only argument for either the Devonian or Triassic age of these sediments is that derived from their color, red sandstones and shales occupying a prominent position in the basin; and the principal evidence of their Primordial age seems to be their proximity to the Boston basin, in Braintree; but, as already stated, the evidence is against the communication of the two basins in either past or present time. The Norfolk County beds are extensively folded, showing at most points high, and often vertical, dips; but in this respect they are as little contrasted with the Carboniferous on the one hand as with the Primordial on the other. In the almost complete absence of eruptive rocks among the beds in question, however, we find a sharp distinction between them and all the Primordial of Eastern Massachusetts.

We entered upon our work with a prepossession in favor of the Devonian age of the belt; but almost at the outset we were struck by the strong resemblance which it presented both lithologically and stratigraphically to the Carboniferous on the south. The Carboniferous of the main Narragansett basin, so far as we have been able to learn from our own observations, and from those of Hitchcock, consists essentially, beginning at the base, of the following groups of rocks:

(1.) A great thickness of conglomerate, which, at the bottom, is sometimes extremely coarse and irregular, holding bowlders

* Jour. Geol. Soc. London, vol. i.

a yard or more in diameter, though the great mass of the rock is composed of pebbles not exceeding three inches in diameter. The higher portions, especially, include considerable sandstone, mostly in thin and irregular beds. All the crystalline rocks of the region are represented among the pebbles of the conglomerate, though granite, quartz and quartzite predominate. The paste is sometimes ferruginous, giving the red conglomerate described by Hitchcock.

(2.) The conglomerate gives way upward to red and gray or green sandstones which have in the aggregate a considerable thickness, certainly not less than six hundred feet. The differently colored sandstones do not appear to be always sharply separated stratigraphically, but it seems probable that in some cases the same horizon is represented by red sandstone at one point and green at another. Yet we are of the opinion that the red color is chiefly characteristic of the lower beds. Pebbly layers, and even considerable beds of conglomerate, sometimes appear in the sandstone; and these are much more abundant in some localities than in others. Both the red and the green sandstones frequently pass into true slates and shales; and in the red shales, especially, the ferruginous character is often very strongly marked.

(3.) Above the sandstone series, and forming the summit of the formation, come the true coal-measures, which, as well described by Hitchcock, consist very largely of a black, highly carbonaceous slate, but also include a large amount of green sandstone and shales, with comparatively little red rock. Conglomerate is rare in this series, though not entirely wanting.

Now, the important point to be made here is, that the first and second series described above agree perfectly in both composition and sequence with the rocks of the Norfolk County basin; that is, the Norfolk County beds are essentially similar lithologically and stratigraphically to the lower Carboniferous of the main basin; but we find in the smaller basin no trace of the highly carbonaceous, plant-bearing shales, and anthracite of the third series.

Furthermore, we have been able, in Wrentham, to trace a direct physical connection between the rocks of the Norfolk County belt, and the conglomerate and sandstone which underlie the coal-measures; so that, even in the absence of paleontological evidence, it seemed reasonably certain that the sediments of this narrow trough were the stratigraphical equivalents of all but the upper series of the Narragansett basin. But, before the close of our field-work, we were, fortunately, able to clinch the proof of their Carboniferous age by the discovery, near the middle of the belt, of characteristic Carboniferous fossils.

The precise locality is the place marked on the map as Rockdale, in the southeastern corner of the town of Norfolk. In this neighborhood there are many large, bold ledges of conglomerate and sandstone, as well as of the underlying granite; and this is, on the whole, the best exposure of the rocks which the belt affords. The fossils are found only in a small-pebbled or arenaceous conglomerate which lies near the top of the first or conglomerate series; and their occurrence along several lines of strike has assisted us in arriving at a knowledge of the structure of the region, the beds being clearly thrown into a series of closed folds. The fossils seem to consist wholly of the molds of Sigillaria, though many of them are so imperfect that, for aught that we could determine, they might be Calamites or Lepidodendron. The coarse texture of the rock has been unfavorable for the preservation of the finer and more characteristic features of the bark. Still, in several cases, enough remains to show that the specimens are unquestionably Sigillaria. The molds are all considerably flattened, and the flattening corresponds in direction with the imperfect cleavage of the rock. They are of various sizes, the smallest being one or two inches in diameter, while the largest observed was about twenty inches by six inches on the cross section. They are usually inclined to the horizon, and the extent to which the arenaceous material formerly filling them has been removed by the action of the weather is remarkable, some of the holes so formed having been probed to a depth of twenty feet or more. About thirty molds in all have been observed.

Although fossils have been found at only this one locality, yet we are not persuaded but that, having learned what kind of impressions are to be looked for, close observation would discover them at other points. Certainly, there is nothing peculiar in the character of the rock at Rockdale; and we feel that the fossils occurring here, taken in connection with the lithological and stratigraphical evidence already referred to, afford ample proof of the equivalence of the Norfolk County series and the conglomerate and sandstone underlying the coal-measures in the main Narragansett basin; and Hitchcock and Lesquereux have already satisfactorily referred these lower Narragansett beds to the horizon of the Millstone Grit. It is worthy of note, too, that the descriptions given by Dawson in his "Acadian Geology" of the Millstone Grit series of New Brunswick and Nova Scotia apply very closely to the rocks in question; and since our coarse conglomerate rests immediately upon the crystallines, it is apparent that Dawson's Carboniferous limestone and lower coal-measures, which taken together represent the Subcarboniferous of the Appalachian region, are probably entirely wanting in Massachusetts and Rhode Island.

We have observed many facts pointing to the conclusion that the Norfolk County beds were deposited in a narrow, elongated basin, similar to that which they now occupy, that is, that the present borders of the belt coincide approximately, at least, with the original shore lines, and that any narrowing which the belt may have experienced is due mainly to folding rather than to denudation.

Along the existing border of the belt, where, of course, the lowest beds of conglomerate outcrop, these are usually mainly, sometimes entirely, composed of pebbles of the immediately adjacent crystallines; and where the conglomerate rests upon granite, the first-formed beds are often a typical arkose which is distinguished with difficulty from the parent rock. This relation of the basal conglomerate to the crystallines is especially noticeable along the south side of the Blue Hills, in Quincy, Milton and Dedham. The carboniferous rocks here, as at most points, form low, level land, and for six miles the conglomerate plain meets abruptly the steep and sometimes almost cliff-like southern slope of this well-marked range of hills, which, on this side, is composed of fine-grained, slightly hornblendic granite, and a variety of petrosilex containing crystalline quartz and feldspar, a true quartz-porphyry or elvanite. Now we find that the conglomerate skirting the base of the Blue Hills is not only almost entirely composed of the débris of these two varieties of rock, but it is also, for the most part, exceedingly coarse, holding many bowlders from one to four feet in diameter, and these are often but imperfectly rounded. It is, in fact, just such material as accumulates on the adjacent coast to-day, where the sea beats against cliffs of granite and petrosilex; and, to our minds, the conclusion is irresistible that the Blue Hills, much higher then than now, towered cliff-like, above the Carboniferous sea, and marked then as now, the northern limit of the deposits of that age.

From the conclusions already stated, an inference of some practical importance may be drawn, viz: although the Norfolk County basin contains only beds of Carboniferous age, yet it is improbable that coal will ever be discovered within its limits, this narrow trough having become filled with sediments and converted into dry land, before the deposition of the true coal-measures began, and this later-formed series having been always, apparently, restricted to a comparatively small part of the main or Narragansett basin.

ART. XLIV.—*Discovery of a new Planetoid, and observations on Hartwig's Comet;* by Professor C. H. F. PETERS. Communication to the editors, dated Litchfield Observatory of Hamilton College, Clinton, N. Y., October 13, 1880.

A BRIGHT *planetoid* was discovered on Oct. 10, and the following positions have been obtained:

1880.	Ham. Coll. m. t.	App. α (219).	App. δ (219).	Log. ($p''\Delta$).	No. of comp.
Oct. 10.	$14^h\ 18^m\ 12^s$	$1^h\ 27^m\ 9^s{\cdot}28$	$+9°\ 6'\ 46''{\cdot}4$	0·553 0·705	10
Oct. 11.	13 19 58	1 26 27·86	+8 52 19·6	0·342 0·699	10

The position of Oct. 11 depends upon that of Dm. $+8°{\cdot}252$, a star of $8^m{\cdot}8$, but of which no accurate determination is found. It has been assumed for 1880·0:

$$\alpha = 1^h\ 29^m\ 45^s{\cdot}0 + c. \qquad \delta = +8°\ 48'\ 20'' + c',$$

so that the planet's coördinates will receive corresponding corrections, when the star's place has been better determined.

The magnitude of the planet was estimated at $9^m{\cdot}3$, and its relatively great nearness to the earth is, besides, concluded from the great apparent motion, amounting to 43^s and $15'\ 14''$ in 24 hours.

I append such of my observations on the *Comet Hartwig*, as far as the comparison stars have been determined.

1880. H. C. m. t.	α	δ	Log. ($p''\Delta$)	No. of Comp.	Comp. star.
	h m s	° ′ ″			
Oct. 3.	7 18 29	15 27 12·46	+27 15 49·3	0·842 0·645	5	W_2. $15^h{\cdot}654$
" 3.	9 10 45	15 28 26·34	+27 11 54·7	0·862 0·767	5	α Coronæ.
" 8.	7 33 23	16 30 53·87	+22 40 57·3	0·803 0·651	10	W_2. 16^h 970 & 976
" 10.	8 27 55	16 49 17·68	+20 55 17·1	0·830 0·704	7	W_2.16^h1602

In Weiss's Catalogue the right ascension of $16^h{\cdot}970$ ought to be corrected by $+10^s$.

On October 9, when the moon did not yet interfere, the tail could be followed, by a five-inch seeker, for three or four degrees. The nucleus, though not quite stellar, shows a good concentration for accurate pointing.

ART. XLV.—*The Discovery of Oxide of Antimony in extensive lodes in Sonora, Mexico;* by E. T. COX, of Tucson, Arizona Territory.

[Read before the Boston meeting of the American Association for the Advancement of Science, August 27, 1880.]

UP to the present time the antimony of commerce has been mostly obtained by the reduction of the sulphide, and though this ore is widely distributed over the globe, it is, as a rule, associated with a variety of mineral substances that obstruct

reduction and add to the cost of purifying the metal. These sulphides are also found in such sparse quantities, that the metal usually commands from three to four times the price of lead, and fully as much as that of tin or copper. At present the supply of sulphides of antimony for the English smelters is obtained from Algeria, Spain and Ceylon. Small quantities of oxide of antimony ores have been found in portions of Europe and in Ceylon, but at no time in such quantities as to elicit special attention. When, therefore, about a year ago, I called the attention of English metallurgists and smelters to the occurrence of vast lodes of almost pure oxide of antimony in the district of Altar, Sonora, Mexico, thirty miles from the Gulf of California, it seemed too marvelous for their belief.

A company of gentlemen of Boston, Mass., now have control of these antimony mines, and the ore will soon be in the hands of smelters.

The geological features of the country where this ore abounds are similar to those of Southern Arizona. The mountains are in short, narrow ranges, having for the most part a northerly and southerly trend. Their crests are either rugged or well-rounded cones, according to the nature of the rocks forming their mass. Between these ranges, we have what is called mesa or table land; the latter is formed of the debris of the mountains. This material is of so loose and porous a nature, that the small amount of rain which falls sinks through it and leaves the land dry and arid. As far as I have been able to make out the order of the rocks forming these mountain chains, we have first granite, and this is flanked by Subcarboniferous limestone, in most places so crystalline as to obliterate all traces of fossils. Protruding through these and forming the mountain peaks, we have porphyry, quartzites, basalt, diorites and trachytes.

The country rock in the immediate vicinity of the antimony mines is quartzite and limestone. The lodes are from four to twenty feet wide, and exploitation work, carried to a depth of thirty feet, shows that the fissures are filled from wall to wall with the oxide of antimony, almost pure and remarkably uniform in character. The course of the lodes is nearly north and south; the pitch is high to the east. The area over which the ore is found may be roughly stated to be five or six miles long and half a mile or more wide.

The Boston Company controls nine mines, each of which is a full Mexican claim, 800 meters (2624′ 8″) long and 200 meters (656′ 2″) wide. On three of the mines, the crop, which is solid oxide of antimony, stands up boldly above the general surface and may be traced along the claims for many hundred feet. As stated above, the ore, so far as explorations have exposed it, is

almost pure oxide of antimony, the little impurity it contains being silica. The fire assays show it to contain from 60 per cent to 70 per cent of pure metal, and I have estimated the entire lode to average 50 per cent. By selection the average may be augmented. On going down to a greater depth in the lode, it is possible that the oxides may give place to sulphides, but thus far there is not the slightest evidence of any change.

This discovery is destined to produce a marked influence upon the production of metallic antimony and to greatly extend its uses.

Professor S. P. Sharples, of Boston, after an examination of many specimens of the oxide of antimony, received from me, has made the following statement: The mineral varies in color from almost white, to a very dark brown. The specific gravity of one of the purest specimens, is 5·07, and it contained 5 per cent of water, and 75 per cent of antimony. This composition and specific gravity approach very closely the same for *stibiconite*.

The mineral is only very slightly soluble in hydrochloric or nitric acid, or aqua regia. Fusion with bisulphate or soda, only partially resolves it. It is, however, readily and easily decomposed in a platinum crucible with carbonate of soda.

This oxide of antimony has hitherto been found only as a slight coating on other antimony minerals, and it has been difficult to get specimens of it, even a few grains in weight.

The mineral is not easily reduced before the blowpipe, but is very easily reduced in a crucible with powdered charcoal or cyanide of potassium, giving as a single operation buttons of star antimony.

ART. XLVI.—*Experiments made to determine the "Drag" of Water upon Water at Low Velocities;* by the Rev. SAMUEL HAUGHTON and J. EMERSON REYNOLDS, M.D.*

A SPHERICAL ball of granite, unpolished, was suspended by a pianoforte wire, and allowed to hang freely; from the brass collar by which the ball was suspended an index projected on each side, the pointed ends of the indices traversing a graduated horizontal circle, whose center corresponded with the line of suspension. The suspended ball was immersed in water contained in an iron tub.

The weight of the granite ball was 22452·85 grams, and its mean diameter was 251·46 millimeters. The length of the

* From the Proceedings of the Royal Irish Academy, read Feb. 23, 1880. The term "Drag" is to be understood as signifying the combined effects of friction and viscosity

wire of suspension was 610·8 centimeters, and its diameter was 0·889 millimeter. The diameter of the iron tub was 2 feet 4 inches, and the depth of water contained in it was 1 foot 9 inches.

The method of observation was as follows: the indices of the ball having arrived at the zero of rest, the ball was then displaced by a torsional movement of the wire, and allowed to regain its position of rest by a succession of vibrations of diminishing amplitudes.

The quantities observed were, the time of vibration and the rate of diminution of the amplitude.

The equations of motion of the apparatus are thus found:—

$$\frac{d^2x}{dt^2} - \mathrm{X} = 0; \tag{1}$$

where x=the varying amplitude of any point of the surface of the ball measured from the zero of rest; X = the tangential forces of torsion and "drag" acting at the point x.

If we assume that for low velocities the friction will be proportional to the velocity, we shall have

$$\mathrm{X} = k^2x - f\frac{dx}{dt}; \tag{2}$$

where k is a coefficient depending on torsion, and f is a coefficient depending on "drag."

It is easy to see that the complete integral of the equation of motion,

$$\frac{d^2x}{dt^2} + f\frac{dx}{dt} + k^2x = 0, \tag{3}$$

must be of the form

$$x = ae^{mt}\cos nt + be^{mt}\sin nt, \tag{4}$$

where a and b are arbitrary constants, and where m and n have the values

$$m = -\frac{f}{2}; \quad n = \sqrt{k^2 - \frac{f^2}{4}}. \tag{5}$$

If we reckon the time from the commencement of the oscillation, equation (4) reduces to

$$x = ae^{mt}\cos nt. \tag{6}$$

If T denote the time of a complete double oscillation, we find from the above

$$\theta_n = \theta_o e^{-\frac{fn\mathrm{T}}{4}}, \tag{7}$$

where θ_n=amplitude of the $(n+1)^{th}$ vibration; θ_o=amplitude of the first vibration.

From (7) we obtain the following working equation, for use in the calculations to determine the coefficient of friction:—

$$f = \frac{2}{n\mathrm{T}}\log_e\left(\frac{\theta_o}{\theta_n}\right). \tag{8}$$

Also, we have $$n = \frac{2\pi}{T} = \sqrt{k^2 - \frac{f^2}{4}};$$

from which we obtain, after some reductions,

$$T = \frac{4\pi}{\sqrt{4k^2 - f^2}}. \tag{9}$$

If we introduce into this equation the value of f determined by (8), we obtain k, which depends on the torsion only.

From careful experiments made by means of the apparatus described at the beginning of this paper the following value has been obtained for the coefficient of "drag":

$$f = \frac{1}{307{\cdot}057}$$

From this value of f we can determine the relation between the slope of a water-surface and its velocity. We have, for the equation of motion of the surface,

$$\frac{d^2x}{dt^2} = g \sin i - f\frac{dx}{dt}; \tag{10}$$

where g denotes the force of gravity, i the slope of the surface, and x the distance of any particle from the origin measured in the direction of the motion. If v denote the velocity of a particle, equation (10) becomes at once

$$\frac{dv}{dt} + fv = g \sin i; \tag{11}$$

which gives, by integration,

$$e^{ft}(g \sin i - fv) = \text{const.} \tag{12}$$

This indicates that the velocity will increase from zero up to the value given by

$$g \sin i - fv = 0, \tag{13}$$

after which it will remain constant forever.

The final constant velocity given by equation (13) is

$$v = \frac{g \sin i}{f} = 32{\cdot}2 \times 307{\cdot}057 \sin i. \tag{14}$$

If we express the velocity in feet per second, and call h the slope per mile, we find

$$v = 1{\cdot}8726 \times h \text{ ft. per second}; \tag{15}$$

which is equivalent to

$$v = 30{\cdot}642\, h \text{ miles per day}. \tag{16}$$

Dr. Carpenter has proposed to explain the phenomena of ocean circulation by the greater height of the water at the equator as compared with that at the poles.

If we call the distance from the equator to the pole 6,000 miles, and suppose the velocity of the surface current toward the pole to be only one mile per day, we find from equation (16), that this would require a head of water at the equator

$$h = 195{\cdot}80 \text{ feet.}$$

No such difference of level can be admitted between the equilibrium levels of the equatorial and polar oceans. The latest accurate estimate of the difference is that made by Mr. Croll, viz., $4\frac{1}{2}$ feet. This head of water, if it could produce an oceanic flow at all, would be one at the rate of one mile in 42·567 days; or a flow that would occupy 700 years to pass from the equator to the poles.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the determination of Carbon dioxide in expired air.*—Marcet has described a modification of Pettenkofer's apparatus for determining the amount of carbon dioxide contained in expired air. He uses a cylinder of thick glass, of about two liters capacity, ground flat at both ends and closed by disks of thick glass, closely fitting the openings and kept in place by brass collars. The upper glass disk is perforated with three holes, to contain respectively a thermometer and two stopcocks. The lower disk has one opening, for the insertion of a stopcock. The cylinder is supported on a tripod. The air to be analyzed is collected in a rubber bag, those used by Marcet holding 39·3 and 64·8 liters under the pressure of one inch of water. The bag is connected to the cylinder by one of the upper openings, and the cylinder is put in communication with the air-pump by the lower one. After exhausting to 20 or 30 mm. pressure the air from the bag is allowed to enter the cylinder; this operation being repeated till the cylinder is filled with air from the bag. By means of the thermometer and a manometer attached to one of the stopcocks, the temperature and pressure are noted. The stopcocks are now closed and communication interrupted with the bag and the air-pump. In place of the tube to the bag, a pipette containing 100 c.c. of normal barium hydrate solution is connected to the cylinder; and in place of the manometer a small bag of vulcanized rubber is inserted to receive the air expelled by introducing the barium solution. On opening the stopcocks of the pipette and the connecting tube, the solution passes into the cylinder. After agitation, the milky liquid is drawn off into a 100 c.c. bottle and closely corked. Subsequently, at convenience, 25 c.c. of this liquid is removed with a pipette, 100 c.c. of distilled water is added, the solution is placed in a burette and added to 5 c.c. of an oxalic acid solution of such strength that 1 c.c. corresponds to one milli-

gram of CO_2, until neutralization is effected. From the data thus given the weight of the carbon dioxide is calculated.—*J. Chem. Soc.*, xxxvii, 493, July, 1880. G. F. B.

2. *On the Atomic Weight of Ytterbium.*—NILSON has continued his researches upon the rare elements of the mineral euxenite, having had the good fortune to receive from Professors Nordenskiöld and Waage more than ten kilograms of this substance. The earth from it, which was formerly called erbia and supposed to be the oxide of a single element, he now finds to contain not less than seven different oxides, scandia, ytterbia, thulia, erbia, terbia, the earth which Soret calls x, and yttria. To extract them, the finely pulverized mineral was placed in a platinum dish, in quantities of about 400 grams, mixed with four times its weight of hydropotassium sulphate, and fused over a powerful gas lamp. The fusion was completely extracted with cold water, decanted from the undissolved metallic acids, precipitated with ammonia, the hydrates thus obtained washed out, dissolved in nitric acid, boiled, again decanted from the metallic acids, precipitated with oxalic acid, washed, dried and ignited. In this way 2½ kilograms of the mixed earths was obtained. After boiling with water to free it from potassium carbonate, it was dissolved in nitric acid and the nitrate evaporated and fused until the weight was twice that of the mixed earths. On solution in water, a residue remained of basic nitrates of thorium, cerium, uranium and iron. The filtrate gave a beautiful fused nitrate, which was subjected to the long series of partial decompositions already previously described. The strongest bases, didymium, yttrium and terbium accumulated in the first mother-liquors so that the principal solution after seven decompositions, contained no didymium. In the mother-liquors from 8 to 30 the absorption-bands of the so-called erbia increased successively in intensity, the solution containing finally nearly the whole of the earths which are characterized by absorption bands. Cleve having worked up 15 kilograms of gadolinite at the same time, these two chemists had at least 6–7 kilograms of the earths between them. So they divided the work, Cleve taking erbia proper and thulia, and Nilson ytterbia and Soret's earth x. The latter's present paper is upon ytterbium. After 68 decompositions, the syrupy nitrate solution showed not a trace of any absorption band, and, after the scandia had been separated, contained only pure ytterbia.* The solution of the nitrate was treated with H_2S, and the filtrate precipitated with oxalic acid. The oxalate was ignited, the earth converted into nitrate and divided by partial decompositions into seven fractions. Each of these was converted into sulphate by dissolving a weighed quantity of the earth in nitric acid, adding sulphuric acid in excess, and evaporating till no more fumes appeared. The atomic weight of ytterbium as obtained from these seven fractions, calling ytterbia Y_2O_3, is as follows: 173·21, 173·03, 173·08, 173·00, 173·01, 172·84,

* Series 61–68 contained, beside ytterbia, only the oxide of a metal to which Cleve has given the name of thulium.

172·91; or 173·01 as a mean. The author also describes ytterbia, and its hydrate, nitrate, anhydrous and hydrated sulphates, selenite, and oxalate.—*Ber. Berl. Chem. Ges.*, xiii, 1430, July, 1880. G. F. B.

3. *On the Atomic Weight of Scandium.*—Nilson has also communicated the results of his researches upon the atomic weight of scandium. For its separation from ytterbium, two methods may be used: the first, based upon the fact that scandium nitrate is far more easily decomposed by heat than the corresponding ytterbium salt; and the second, which rests on the behavior of scandium sulphate to a saturated solution of potassium sulphate; a double sulphate $(K_2SO_4)_3$. $Sc_2(SO_4)_3$ being deposited, while ytterbium sulphate is easily soluble in such a solution. Three grams of the mixed earths were dissolved as neutral sulphate in a few c.c. of water, and the solution was gradually saturated with potassium sulphate by hanging fragments of this salt in it in a platinum basket. In a few hours the walls and bottom of the vessel were covered with the crystalline double salt. After a couple of days, it was collected and washed. A weighed quantity of the earth from the filtrate converted into sulphate gave an atomic weight of 172·88, showing this filtrate to contain pure ytterbium. The potassium-scandium sulphate itself was converted into nitrate and fractionally decomposed. Four products were obtained which gave atomic weights of 80·07, 49·47, 49·72, and 46·70; showing that some ytterbia had come down with the scandium. From this last fraction, four further fractions were obtained and the pure scandia prepared by igniting the oxalate. This was weighed, dissolved in nitric acid and evaporated with sulphuric acid in excess till fumes no longer appeared. These fractions gave atomic weights of 43·99, 44·07, 44·05, and 44·02 respectively; or 44·03 as a mean. This atomic weight, 44, coincides exactly with that which Mendelejeff derives from his periodic law for ekabor, with the predicted properties of the oxide of which, scandium oxide Sc_2O_3 coincides. The author describes this oxide, and also the hydrate, nitrate, sulphate, selenite and oxalate. The molecular heat of Sc_2O_3 is 20·81.—*Ber. Berl. Chem. Ges.*, xiii, 1439, July, 1880. G. F. B.

4. *On a new Cymene in Rosin oil.*—Kelbe has examined the lighter oils obtained from the distillation of rosin and finds that they contain a new cymene. After washing with sodium hydrate solution, and fractioning, several products are obtained of constant boiling points. One of these boiling at 170°–178° C., was agitated with concentrated sulphuric acid, in which it dissolved almost completely. On dilution, two layers separated, the upper of which contained the sulpho-acids. This, neutralized with barium carbonate while hot, deposited on cooling brilliant pearly plates of barium α-cymene-sulphate, almost insoluble in cold water, insoluble in alcohol and yielding, when treated with phosphoric chloride and ammonia an α-cymene-sulphamide fusing at 73° C. Further evaporation of the mother liquor gave a second salt, barium

β-cymene-sulphate, as an indistinctly crystalline mass, easily soluble in absolute alcohol. β-cymene-sulphamide prepared from this salt, fuses at 106°–108° C. The cymene prepared from the α-sulpho-salt is a colorless highly refractive liquid of agreeable odor boiling at 173°–175°. By oxidation it gives an acid of high fusing point, probably isophthalic acid. This cymene is distinguished from the parapropytoluenes of Jacobson by the fact that while the sulphamides of these bodies fuse, the one at 112° C., the other at 97°–98° C., this one melts at 73° C. Orthocymene is excluded since it does not yield isophthalic acid on oxidation. Metacymene differs from it in the crystal-form of its barium β-sulpho-salt, and in the ease with which this is converted into the sulphamide. Hence the author is inclined to regard this cymene, at least provisionally, as meta-isopropyltoluene.—*Ber. Berl. Chem. Ges.*, xiii, 1157, June, 1880. G. F. B.

5. *On the preparation of normal Ethyl sulphate.*—Villiers has succeeded in obtaining a larger yield of normal ethyl sulphate $(C_2H_5)_2SO_4$, by effecting the distillation under diminished pressure. To prepare this ether, 200 grams of absolute alcohol is distilled slowly with twice its volume of concentrated sulphuric acid, in as good a vacuum as possible. The yield is 25 to 30 grams. Two layers of liquid appear in the receiver, the lower of which is the ether. It is rectified in vacuo, and boils under a pressure of 5 mm. at 2·5° C. It crystallizes at —24·5°, and alkalies convert it at once into sulphethylate.—*Bull. Soc. Ch.*, II, xxxiv, 25, July, 1880. G. F. B.

6. *On Homatropine.*—Atropine, as is well known, breaks up into tropic acid and tropine. Ladenburg succeeded in reversing the process and in producing atropine from tropic acid and tropine. This led him to the synthesis of an entirely new class of alkaloids, which he called tropeines, produced by the action of acids upon tropine in presence of hydrochloric acid. The tropeine of mandelic or oxytoluylic acid, which he calls oxytoluyltropeine or homatropine, while possessing equal mydriatic power with atropine, yet passes off much more rapidly, in 12 to 24 hours. Merck has obtained it crystallized from solution in absolute ether. It fuses at 95·5° to 98·5°, and has the formula $C_{16}H_{21}NO_3$.—*Ber. Berl. Chem. Ges.*, xiii, 106, 1081, 1340, July, 1880. G. F. B.

7. *On Carbonyl Hæmoglobin.*—Weyl and Von Anrep have proposed to use the behavior of oxy-hæmoglobin and of carbonyl-hæmoglobin toward oxidizing agents as a means of detecting the latter in blood poisoning. While 1 c.c. iodine solution (1 grm. KI, 0·05 grm. I, 1 liter water) produces in blood containing oxygen the bands of methæmoglobin immediately, in blood containing carbonous oxide these bands appear only after four days. In oxygenated blood, $\frac{1}{2}$ c.c. of permanganate solution (0·025 per cent) gives the bands at once, the blood remaining clear and becoming yellowish-green in color. Blood containing CO remains red, becomes turbid and shows no bands. The quantity of the oxidizing agent required to produce the bands increases with the

quantity of CO present. A one per cent aqueous solution of pyrocatechin or of hydroquinone also causes the appearance at once of the methæmoglobin bands in blood containing oxygen; while carbonyl blood is unchanged. In this test, the blood is heated with the phenol to 40° for 15 minutes.—*Ber. Berl. Chem. Ges.*, xiii, 1294, July, 1880. G. F. B.

8. *Change of wave length by movement of the source of light.*—M. L. THOLLON points out the peculiar fitness of a group of iron lines in the spectrum for observation on changes in wave length produced by the approach or recession of the sources of light. The wave length of these iron lines are b=5976·1 and c=5974·6; to the left of b is a telluric line a=5976·35 and to the right of c a telluric line d=5974·36. When the edge of the solar disc is observed it is found that the iron lines change while the telluric lines remain in the same position they assume when the center of the solar disc is observed.—*Comptes Rendus*, No. 7, 1880, p. 368. J. T.

9. *Successive transformations of the photographic image by prolonged action of light.*—M. J. JANSSEN states the following facts in extension of those previously communicated by him: (1.) The ordinary negative image. (2.) A first neutral state. The plate becomes uniformly obscure under the action of the developer. (3.) A positive image which succeeds the first neutral state. (4.) A second neutral state, opposite to the first, in which the plate becomes uniformly clear under the action of the developer. (5.) A second negative image, resembling the ordinary negative image, but differing from it by intermediate states and by the enormous difference of the luminous intensity which is necessary to obtain it. (6.) A third neutral state—in which the negative image of the second order has disappeared, and is replaced by a dark uniform tint.—*Comptes Rendus*, No. 4, 1880, p. 199.

Captain Abney enters into an explanation of the reversal of the developed photographic image in the Philosophical Magazine, September, 1880, p. 200. J. T.

10. *Change of the zero point of a thermometer.*—Professor J. M. CRAFTS shows (1.) that the zero point rises more rapidly in thermometers made of French crystal than in those made from glass without oxide of lead. (2.) The elevation of the zero point is much more rapid at first, and probably tends toward a limit under long heating at a fixed temperature. (3.) The zero point which has risen under prolonged heating at a high temperature retains this elevation when the thermometer is kept at the ordinary temperature; and the effect produced by the elevated temperature renders the thermometer more stable under the influence of lower temperatures. Professor Crafts shows that the theory of Depretz is sustained by his own experience. In other words the changes in glass are due to the interior work of the molecules in coming back to positions of equilibrium, and probably not to the effects of pressure.—*Comptes Rendus*, Nos. 5 and 7, 1880, pp. 291–370. J. T.

11. *On the electric discharge in Rarefied gases.*—Dr. EUGEN GOLDSTEIN, in a preliminary paper on a new differentiation of Electric Rays maintains the following points: (1.) The production of light by an electric ray from the negative pole in highly rarefied gas, takes place only when the ray strikes upon a solid obstacle. (2.) It is not the whole length of the ray which produces the light, but only the end of it furthest from the negative pole. (3.) The cause of the production of the light is to be sought in an optical action. (4.) The modification of the end of the ray is produced, not only when the ray impinges on a fluorescent wall, but also whenever it falls on any solid substance. (5.) The differentiation in question is not associated with a particular pressure. (6.) The phenomenon is not associated with any particular intensity of discharge. (7.) The same differentiation occurs with the "secondary negative light," a name given to the light produced at any point of the discharge at which a contraction of the tube is introduced. (8.) The excitation of light by the ends of the negative rays is not of the same kind as the illumination called forth in the surrounding walls of the tubes by the stratification of the positive light when the rarefaction is small.—*Phil. Mag.*, September, 1880, p. 173.

Dr. Goldstein's paper is to be continued and will prove of great interest in connection with Crookes' experiments in the same direction. J. T.

12. *Heat theory of the development of Electricity.*—H. J. L. HOORWEG maintains the theory that the development of electricity is due to a redistribution of kinetic energy in the form of heat. Electricity results from thermo-dynamic relations between the points of contact of heterogeneous substances. Peltier's phenomena—the development of electricity from evaporation, from diffusion, from osmose, from capillarity are, in turn, discussed from the point of view of this theory.—*Annalen der Physik und Chemie*, No. 9, 1880, p. 133.

13. *Introduction to the study of Chemical Reactions;* by Dr. PHIL. EDMUND DRECHSEL. Translated by N. Fred. Merril, Ph.D. New York: John Wiley & Sons. 138 pp. 12mo.—This volume is occupied with the application of the most recent and advanced chemical philosophy to the elucidation of the chemical changes that are involved in elementary qualitative analysis. The work of both author and translator is excellently done. The terms Molecules, Atoms and Reactions are first defined; Valence and its laws; Oxidation and Reduction; Solution of Metals and Metallic Oxides; Manner in which Reagents work; Characteristic and Special Reactions of Bases and Acids, are the titles of the remaining chapters. The book must be very serviceable to students of analytical chemistry in acquiring familiarity with the theory of their work. S. W. J.

14. *Water analysis for Sanitary purposes, with hints for the interpretation of results;* by E. FRANKLAND. 149 pp. 8vo. Philadelphia, 1880 (Presley Blakiston).—This little volume gives

in clear and concise form the methods employed in the analysis of water for sanitary purposes, and the determination of the various ingredients which may be present. It contains much useful information in regard to the sanitary effect of different kinds of water, the comparative danger arising from the various possible impurities, and concludes with the Report of the Rivers Pollution Commissioners of Great Britain.

II. Geology and Natural History.

1. *On the Geological action of the Humus acids;* by Alexis A. Julien, of New York. 100 pp. 8vo. From the Proceedings of the American Association, vol. xxviii, Saratoga Meeting, 1879. Salem, 1880.—This extended memoir treats of the "acids existing in humus" according to chemists, or rather some chemists, and of their distribution through surface and subterranean waters; and then of the action of organic acids in taking up iron oxide, silica and other mineral ingredients, and producing changes in minerals and rocks and making mineral depositions. Under the long-recognized principle that iron is taken up by such acids and thus removals, bleachings and depositions are made, he brings forward the case of the bleaching of sands on the New Jersey coast and elsewhere, which he attributes to this agency. The reader will derive from the memoir an enlarged view of the efficiency of this agency in geological operations, but in the case of consolidations, mineral formations, silicifications and many other of its alleged results will wish that the suggestions had been fortified by experiment.

2. *Catalogue of Minerals and Tables of Species;* by A. E. Foote. 97 pp. 8vo. 1880. Philadelphia, Penn.—This catalogue, besides containing a list of mineral species, a tabulation of some of their character, and republications of descriptions of several new American minerals, gives some excellent original figures (from photographs) of crystals of the amazon stone from Colorado, rutile and brookite from Arkansas, and some other species.

3. *Bulletin of the Nuttall Ornithological Club*, Cambridge, Mass.—No. 4 of the fifth volume of the Ornithological bulletin has recently been issued. It contains a large variety of interesting matter and shows great enthusiasm in its numerous contributors. In an article by Dr. Coues, "Behind the Veil," we are treated to much of peculiar interest, not only in the personal history of Wilson and Audubon, but also in the early history of American Ornithology itself. A. E. V.

4. *Life on the Seashore, or Animals of our Coasts and Bays;* by James H. Emerton. 138 pp., 12mo. 161 cuts. George A. Bates, Salem, Mass. 1880.—In this book the author has given very interesting and popular accounts of the more common forms of animal life occupying the shores; the surface; and the bottoms of our northern sea-coast, with good illustrations of a large number of them. The large amount of information concerning the habits and transformations of many of these animals

gives additional interest to the book. Descriptions of the apparatus and the modes of capturing and preserving specimens of marine invertebrates are also given. It is an admirable introduction to the study of marine zoology. A. E. V.

5. *The Natural History of the Agricultural Ant of Texas, a Monograph of the Habits, Architecture and Structure of Pogonomyrmex barbatus;* by HENRY CHRISTOPHER MCCOOK. 310 pp. 8vo, with 24 photolithographic plates. Philadelphia, 1880. (J. B. Lippincott & Co.)—This volume gives at great length the final results of an enthusiastic study of the life-history of the agricultural ant of which some accounts were published nearly twenty years ago by Buckley and Lincecum. Considerable doubt has been expressed in regard to the accuracy of these early observations, and Mr. McCook, in 1877, visited Texas for the purpose of settling the questions which Buckley's and Lincecum's reports had raised. The later observations in the main confirm the earlier ones, but are far more complete and minute and add many new facts to the remarkable history. The present work is eminently popular in style and certainly very readable and thoroughly interesting, though often exceedingly diffuse, and deserves a wide circle of such readers as have been delighted with the somewhat similar work of Moggridge, "Harvesting Ants and Trap-door Spiders." It may add to the interest in Mr. McCook's volume to call attention to a note, by the Rev. G. K. Morris, in the American Naturalist for September, p. 669, ascribing harvesting habits to an ant (a species of *Pheidole*) in New Jersey. S. I. S.

III. ASTRONOMY.

1. *Photographs of the Nebula in Orion;* by Professor HENRY DRAPER, M.D.—During the night of September 30, 1880, I succeeded in photographing the bright part of the nebula in Orion in the vicinity of the trapezium. The photographs show the mottled appearance of this region distinctly. They were taken by the aid of a triple objective of eleven inches aperture made by Alvan Clark and Sons, and corrected especially for the photographic rays. The equatorial stand and driving clock I constructed myself. The exposure was for fifty minutes. I intend at an early date to publish a detailed description of the negatives.

New York, Oct. 2d, 1880.

2. *Astronomical Observatory at Rochester N. Y., under the charge of* Professor SWIFT.—The new Astronomical Observatory, at Rochester, is to have the third largest telescope in size in America. The telescope will be twenty-two feet in length and its lens sixteen inches in diameter. The Observatory is named after Mr. H. H. Warner, by whom it has been most liberally endowed, and its locality is one of the most commanding in Rochester. With Professor Swift as its observing astronomer, great results may be expected from the new Warner Observatory.

IV. Miscellaneous Scientific Intelligence.

1. *Manual of Cattle-Feeding. A Treatise on the Laws of Animal Nutrition and the Chemistry of Feeding-Stuffs in their application to the feeding of Farm Animals. With illustrations and an Appendix of useful tables;* by Henry P. Armsby, Ph.D., Chemist to the Connecticut Agricultural Experiment Station. New York: John Wiley & Sons. 1880.—This volume of 525 clearly printed 12mo pages is divided into three parts, viz: Part I. The General Laws of Animal Nutrition, comprising eight chapters, treating respectively on the Composition of the Animal Body; Components of Fodders — Nutrients; Digestion and Resorption; Circulation, Respiration and Excretion; Methods of Investigation; Formation of Flesh; of Fat; Production of Work. Part II, on Feeding Stuffs, in three chapters, discusses Digestibility; The Coarse Fodders; Concentrated Fodders. Part III treats of the Feeding of Farm Animals, in seven chapters, viz: Feeding Standards; Feeding for Maintenance; Fattening; Feeding Working Animals; Production of Milk; Feeding growing animals; Calculation of rations. An Appendix includes four tables: I. Composition of Feeding Stuffs; II. their Digestibility; III. Feeding Standards for farm animals; IV. Proportions by weight of the various parts of cattle, sheep and hogs.

It may be safely asserted that Dr. Armsby's work contains the most complete and satisfactory exposition of the present state of knowledge on the subjects it treats of, that is extant. Not only is it very far in advance of anything that has hitherto appeared in the English language, but no other tongue, not excepting the German, can to-day offer its equal. The book treats of a difficult and complicated subject, but the difficulties are approached in a manner adapted to make their mastery easy to the careful reader who possesses a moderate knowledge of chemistry and physiology. The method and spirit of the book deserve the highest praise as in evident accord with the best tendencies of exact science. The whole field of investigation has been surveyed. Excellent discrimination is shown in the selection of illustrative experimental data, and to a great degree all essential facts are so presented that the reader cannot fail to see their force. The author fairly presents the claims of rival or opposing theories, and clearly indicates where his conclusions rest on solid facts, and where, in default of accurate knowledge, it is for the present necessary to accept probabilities as our guide, or even to remain quite in the dark. The student of physiology will find in this work the results of a vast amount of investigation undertaken in the German Experiment Stations, with which our physiologists are imperfectly acquainted; and the farmer who is exercised on the practical questions of cooking fodder, the use of concentrated foods, fensilage, compounding of rations, exclusive meal feeding, influence of food on milk, etc., can read in Dr. Armsby's pages the essence of what is positively known on these subjects. S. W. J.

2. *Contributions to the Archæology of Missouri* (30 pp. 4to.) by the Archæological Section of the St. Louis Academy of Science. Part 1, *Pottery*, 30 pp. 4to, with 23 plates.—This valuable and well-illustrated contribution to archeology consists of two memoirs: one, a general sketch of the archeological remains in southeastern Missouri by W. B. POTTER; the other, on the ancient pottery of the same region, by Dr. EDWARD EVERS, in which the large number and often quite artistic forms represented in the plates are treated of as to locality, conditions of occurrence, and other particulars.

3. *Spectroscopic Notes by Professor Young.*—In this article, in the 8th line from the top of page 358, the letter Y should be G.

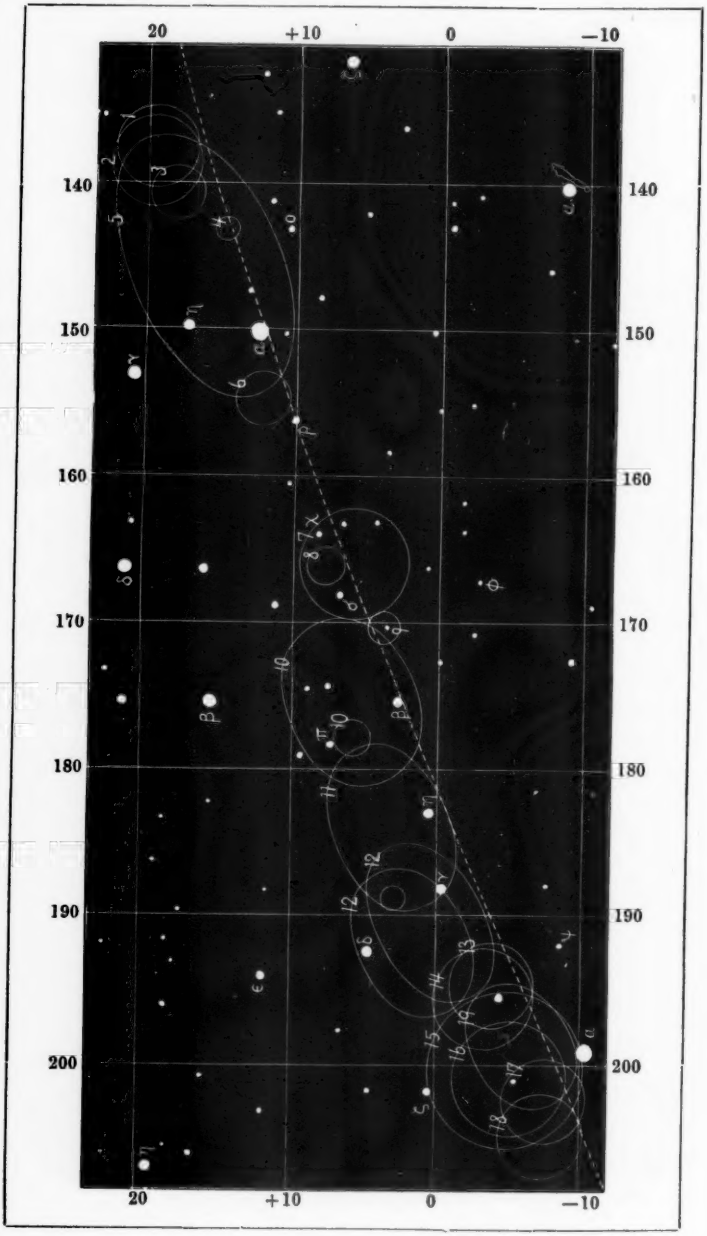
OBITUARY.

Professor BENJAMIN PEIRCE, LL.D., F.R.S., Perkins Professor of Astronomy and Mathematics at Harvard University, died at his home in Cambridge, Oct. 6, in the seventy-second year of his age, and the fiftieth of his connection with the University. His father and mother were both distinguished for their acuteness of mind, and his instructor, Nathaniel Bowditch, predicted that the boy Peirce would be one of the first mathematicians of his day—a prediction fully realized. In 1831, two years after graduation at Harvard College, he was appointed mathematical tutor, in 1833, professor, and in 1842 he was appointed to the chair he filled and honored until his death. He found it consistent with his devotion to science to do much work in connection with other institutions than Harvard during his professorship. Among these services, in 1849 he undertook the revision of the American Ephemeris and Nautical Almanac, for which he prepared his valuable lunar tables. In 1855 he was one of the commission to organize the Dudley Observatory. From 1867 to 1874 he was in charge of the United States Coast Survey and rendered great service to the country and to science by recruiting the languishing financial strength of that service and impressing upon Congress the duty of effectually reorganizing and pushing forward the work so much retarded by the civil war. He was one of the original members of the National Academy. He threw all his influence into the organization and successful development of the American Association, which he always held should be free from class distinctions, and to which he would never be elected in the higher class of fellows but was a member only. He contributed very largely to make the American Academy of Boston what it is, and throughout the whole of the scientific literature of the past fifty years Peirce's name frequently occurs as a contributor upon mathematical and physical topics. In his own department of the University he thoroughly impressed the concise methods of thought so effectually used in his greater works. The teaching at Harvard is based upon his methods and notation, and these methods are models of perspicuity and elegance. In physical astronomy perhaps his greatest works were

in connection with the planetary theory, his analysis of the Saturnian system, his researches regarding the lunar theory, and the profound criticism of the discovery of Neptune following the investigations of Adams and of Leverrier. As a mathematician, his work on Analytical Mechanics, his treatise on Curves, Functions and Forces, and his memoir on Linear Associative Algebra all evince extraordinary originality and genius. Many of his detached papers, relating to the theory of observing, and the solution of special problems, show an appreciation of the needs in applied mathematics which perhaps has not been exhibited by the same order of genius since the death of his friend and admirer, Gauss. His originality was fostered by his habit of examining a new mathematical question for himself, and only referring to the work of other geometers after he had first fairly exerted his own powers of analysis.

His genius was early recognized abroad and elections to the Royal Societies of London, Edinburgh and Göttingen and to various continental societies were awarded him. The versatility and breadth of his mind is partly shown by the scope of his papers; but to those who came in daily contact with him he showed such a penetrating discernment of the conditions of a problem, he made such sagacious suggestions regarding the inferences to be drawn from the data before him, he showed such a wonderful power of generalization, that the papers he has given to the world only seem to indicate the quality of work his mind had constantly before it, and to afford no idea of the multitudinous problems he had been interested in and discarded as soon as the solution became evident to himself. He habitually ascribed to his listener a power of assimilation which the listener rarely possessed. He assumed his readers could follow wherever he led; and this made his lectures hard to follow, his books brief, difficult and comprehensive, and his best work only when his listeners were students trained in his methods who had already attained some skill as mathematicians. He was personally magnetic in his presence. His pupils loved and revered him, and to the young man he always lent a helping hand in science. He inspired in them a love of truth for its own sake. His own faith in Christianity had the simplicity of a child's; and whatever radiance could emanate from a character which combined the greatest intellectual attainment with the highest moral worth, that radiance cast its light upon those who were in his presence. His works are already scarce and some of them hardly obtainable; notably the second volume of his "Curves, Functions and Forces," and his memoir on "Linear Associative Algebra." It is much to be desired that the manuscripts he has left be completed so far as possible and made accessible; and this work could devolve on no person so well qualified as is his distinguished son, Professor James Mills Peirce. L. W.

William Lassell, F.R.S., the distinguished astronomer, and eminent in connection with the history of reflecting telescopes, died on the 4th of October, in the 82nd year of his age.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